CHEMICAL ATTRACTION.

AN

ESSAY

IN FIVE CHAPTERS.

I. THE LAWS OF COMBINATION.
II. THE ELECTRO-CHEMICAL THEORY.
III. THE ATOMIC THEORY OF DR. DALTON.
IV. THE THEORY OF VOLUMES OF M. GAY LUSSAC.
V. THE AGENTS OPPOSING CHEMICAL ATTRACTION.

WITH

AN HISTORICAL INTRODUCTION,

AND SEVERAL

ILLUSTRATIVE TABLES.

BY

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TO

EDWARD TURNER,

M.D. F.R.S. L. & E. Sec. G.S.

PROFESSOR OF CHEMISTRY IN THE UNIVERSITY OF LONDON,

&c. &c. &c.

My dear Sir,

There is a sensation of pleasure experienced by an author, when the volume upon which he has spent many an anxious hour is presented to the world. The cacoëthes scribendi is attended with momentary thrills of delight, which amply compensate for the long period of anxiety and study to which its owner is subjected. But the climax of an author's felicity is when he has obtained the consent of some illustrious individual to accept the dedicatory presentation of his work.

With feelings similar to these, Sir, I have inscribed the present volume to you; I now "cast it upon the waters" of the literary world,

being assured that whether it may be received with the encouraging commendation of favourable reviews, or the repulsing acerbity of censorial critiques, it will have attained an object commensurate with the highest hopes of the author's ambition, in affording him an opportunity of placing in close proximity the names of Dr. E. Turner,

And of his obliged servant and former pupil,

GILBERT LANGDON HUME.

PREFACE.

The volume which these remarks will preface, is intended to contain a short, but satisfactory history of Chemistry, and a statement of the progress which has been made in the science. The original matter is decidedly not the principal excuse for presenting it to the world; but it has been the wish of the writer to state the present condition of the science, and to inquire into the causes which have advanced it.

For this purpose the work has been divided into two parts: the Introduction which contains the history—and the Treatise which comprises the science. In the Introduction, the author has selected the most prominent cha-

racters, and has delineated their lives from historians of unimpeachable veracity. The few political remarks are intended to apply to the times in which they occur, and are for the most part introduced as corollaries inferred from the text, and impossible to be denied if the circumstances narrated be correct. Whosoever will take the pains to acquaint himself with the evidence of impartial historians, must coincide with the sentiment that the Puritans were hostile to the advancement of literature and science, and that they were a race of infatuated impostors, who, for the sake of personal aggrandizement, assumed religion as a mask, under which murder and even regicide were perpetrated with impunity. To authenticate the fact, we have only to look around us; the sacred edifices throughout the kingdom mutilated, the shrines of the saints plundered, not from any hatred of idolatry, but to obtain possession of the gold and jewels which had for centuries been entombed: added to this, the learning of the Universities contained in MSS. not to be replaced, was committed to the flames by the unhallowed hands

of these abandoned miscreants, in the ignorant wantonness of fiendish bravado. From a statement of facts like this, the author does not mean to draw any reflections which may be combined into political inuendos as far as regards the present day. The statement is not political, but historical ; not founded upon opinion, but based on fact.

The scientific part of the work is comprised in five chapters. This division was thought prudent, in order to lay before the reader, in as clear a manner as possible, the theory and the fact, in order that he might readily distinguish the one from the other. The authors to whom I am indebted are quoted in the margin, or occasionally in the text. There is one work, however, which I have not directly borrowed from, but which has considerably augmented my information, both historically and scientifically, with regard to the Atomic theory ; I mean the valuable treatise upon that subject exclusively by Dr. Daubeny—a work which cannot be too often or too attentively perused by any who wish to perfect themselves in this branch of the science.

The volume has been the production of a college cloister; its politics confined to times gone by. If it should succeed in amusing one class of readers, and instructing another, the desire of the author will be accomplished. And it is now dismissed, if I may use the words of a literary leviathan, "with frigid tranquillity, having little to fear from censure, or to hope from praise."

CHEMICAL ATTRACTION.

HISTORICAL INTRODUCTION.

In treating of the history of any science, care must be taken that we are not led away by the peculiar inducements which it may hold out for its investigation. We have especial need of this caution in the case of Chemistry: in it we perceive the staid soberness of prose, beautifully contrasted with the romantic fictions of poetry. In the laborious manipulations of the laboratory, we realize the prose—in the study of the ancient alchymists we are presented with the fancies of imaginative poetry. It will, therefore, be my endeavour to select the most striking of these, in the following brief sketch of the history of the progress of Chemical science, from its commencement, according to our best authenticated records, to the present time.

With regard to the word *chemistry,* there is considerable doubt as to its etymological signification; some deriving it from one root, and some from another. Bryant, in his ancient mythology, derives it from *chemia,* and that again from *cham.* The Rev. Mr. Palmer, Professor of Arabic in the University of Cambridge, has given the following as the derivation: "Alchemy, or more properly, alkemy, is so named from the substantive Kyamon, that is, the substance or constitution of any thing." This derivation is certainly in my opinion extremely doubtful, inasmuch as the ancient investigators of this science were not, in the earliest time, anxious about the constitution of bodies, but merely upon the results of their combinations, it being an undisputed maxim, that fire, air, earth, and water, were the four luminary elements, of which all secondary substances were composed. Mr. Brande agrees with Dr. Young in deriving the word from the Coptic word *hhems,* or *chems,* signifying dark, obscure—an etymon which is certainly warranted by analogy, and substantiated by circumstantial evidence. There are other derivations of this word, such as from χυω to melt, χυμος juice; from χιμης a person eminently skilled in the sciences, and from Chêmi, the Coptic name for Egypt; but it would be useless to investigate a subject

so obscured by the want of authentic proof, as to be the occupation of an antiquarian alone. With regard to the antiquity of the word chemistry itself, we find χημεια is first mentioned in the Lexicon of Suidas, who is supposed to have written in the eleventh century. From this fact, and another, namely, the explanation of the word δερας, Dr. Thomson* concludes that chemistry must have been well known to the Greeks in the eleventh century, as it certainly was to the Egyptian s under Dioclesian.

* Vide Thomson's History of Chemistry, vol. I. chap. 1.

11th Century.

We now come to the question, What was then meant by the word at that period? Suidas, in his comment on the word δερας before alluded to, gives us all the information we can desire: "the golden fleece which Jason and the Argonauts took, together with Medea, daughter of Œtes the king." But this was not what the poets represent, but a treatise written on skins, teaching by what means gold might be prepared by chemistry.

The transmutation of the baser metals into gold was undoubtedly the object, the avowed object of the alchymists, which was not only regarded as probable, but was supposed to have been accomplished, being accredited by the attestations of many whose veracity was unquestionable. It was this chimerical delusion that induced many enthusiastic devotees

to expend their all, with the hope of obtaining this invaluable secret, which they termed the Philosopher's stone. To these fancies, vain and absurd as they appear to us, we are indebted for many of our most valuable preparations in the Pharmacopœia of Medicine; this delusion was so powerful, that some, whose judgment has been held up as the ornament of the times in which they lived, have succumbed to its all-engrossing influence. Lord Bacon was a firm believer in the probability of there being an agent possessing these transmutatory powers; and even in the present age, when the impossibility of such a power has been demonstrated by scientific discovery, there are persons who spend their lives, and waste their property, in endeavouring to obtain possession of the invaluable Philosopher's stone. The possibility of its discovery is certainly set aside; but at the same time we cannot but admit, that although chemical analysis is unable to reduce gold to component parts, and we must therefore consider it an elementary body, yet if, in the progress of time, a more powerful analytic agent be found, we may perhaps find gold and the metallic bodies to be constituted of others, and not elementary. Should this be proved, then of course gold may be formed by the union of its newly discovered elements; but till then, all at-

tempts to make it by fortuitous admixtures of other substances, must be looked upon as chimerical and vain. This part of my introduction must not be closed, without adverting to the fact, that there have been one or two impudent impostors, who have, by a dexterous legerdemain, contrived to delude those whom it was their interest to gain over, by the most specious and plausible arguments, and apparently ocular demonstration.* For this purpose all the chicanery of ingenious trickery, all the dogmaticism of arrant quackery, and the pomposity of impudent ignorance, have been brought into the field, to bring over a convert and to extort money. These fellows indeed were the persons who succeeded in converting lead and baser metals into gold. Enormous sums have been exacted from the unsuspicious votary, and many an impudent juggler has by this means obtained the power of making gold, and that ready coined to his use. Some of the alchymists, indeed, profess to have been able to produce gold.† I shall now give from Dr. Thomson, the process of Mangetus for procuring the Philosopher's stone.

"1. Prepare a quantity of spirit of wine, so free from water that it is wholly combustible, and so volatile, that when a drop of it is let fall, it evaporates before it reaches the ground. This constitutes the first menstruum.

* A common trick was, the employment of a crucible with a false bottom; a few pieces of gold being previously inserted between the true and the false bottom.

† For a variety of these stories, the reader may consult Dr. Thomson's Hist. Chem. p. 9.

"2. Take pure mercury, revived in the usual manner from cinnabar; put it into a glass vessel, with common salt and distilled vinegar; agitate violently, and when the vinegar acquires a black colour, pour it off and add new vinegar; agitate again, and continue these repeated agitations and additions, till the vinegar ceases to acquire a black colour from the mercury; the mercury is now quite pure and very brilliant.

"3. Take of this mercury four parts—of sublimed mercury prepared with your own hands, eight parts; triturate them together in a wooden mortar and with a wooden pestle, till all the grains of running mercury disappear. This process is tedious and rather difficult.

"4. The mixture thus prepared is to be put into an aludel or sand bath, and exposed to a subliming heat, which is to be gradually raised till the whole sublimes. Collect the sublimed matter, put it again into the aludel, and sublime a second time. This process must be repeated five times. Thus a very sweet and crystalline sublimate is obtained: it constitutes the salt of wise men, and possesses wonderful properties.

"5. Grind it in a wooden mortar, and reduce it to powder, and pour upon it the spirit of wine (hot), till it stands about three finger

breadths above the powder; seal the retort hermetically, and expose it to a very gentle heat for seventy-four hours, shaking it several times a day; then distil with a gentle heat, and the spirit of wine will pass over, together with the spirit of mercury. Keep this liquid in a well-stopped bottle, lest it should evaporate. More spirit of wine is to be poured upon the residual salt, and after digestion it must be distilled off as before; and this process must be repeated till the whole salt is dissolved and distilled over with the spirit of wine. You have now performed a great work. The mercury is now rendered in some measure volatile, and it will gradually become fit to receive the tincture of gold and silver. Now return thanks to God, who has hitherto crowned your wonderful work with success; nor is this great work involved in Cimmerian darkness, but clearer than the sun; though preceding writers have imposed upon us with parables, hieroglyphics, fables, and enigmas.

"6. Take this mercurial spirit, which contains our magical steel in its belly, put it into a glass retort, to which a receiver must be well and carefully luted; draw off the spirit by a very gentle heat; there will remain in the bottom of the retort the quintessence, or very soul of mercury; this is to be sublimed by applying a stronger heat to the retort, that it may

become volatile, as all the philosophers express themselves—

> Si fixum solvas faciesque volare solutum,
> Et volucrem figas faciet te vivere tutum.

This is our luna, or fountain, in which the king and queen may bathe. Preserve this precious quintessence of mercury, which is very volatile, in a well-shut vessel for further use.

"7. Let us now proceed to the operation of common gold, which we shall communicate clearly and distinctly, without digression or obscurity, that from vulgar gold we may obtain our philosophical gold, just as from common mercury, by the preceding processes, we obtained philosophical mercury.

"8. In the name of God, then, take common gold, purified in the usual way by antimony; convert it into small grains, which must be washed with salt and vinegar till it be quite pure. Take one part of this gold and pour upon it three parts of the quintessence of mercury; as philosophers reckon from seven to ten, so we also reckon our number as philosophical, and begin with three to one; let them be married together like husband and wife, to produce children of their own kind, and you will see the common gold sink and plainly dissolve. Now the marriage is consummated—now two things are converted into one; thus the philosophical sulphur is at hand,

as the philosophers say, 'the sulphur being dissolved, the stone is at hand.' Take then, in the name of God, our philosophical vessel, in which the king and queen embrace each other as in a bed-chamber, and leave it till the water is converted into earth; then the peace is concluded between the water and fire; then the elements have no longer any thing contrary to each other; because when elements are converted into earth, they no longer oppose each other; for in earth all elements are at rest. For the philosophers say, 'When you shall have seen the water coagulate itself, think that your knowledge is true, and that your operations are truly philosophical.' The gold is now no longer common, but ours is philosophical on account of our processes; at first exceedingly fixed, then exceedingly volatile, and finally exceedingly fixed: and the whole science depends upon the change of the elements. The gold at first was a metal; now it is a sulphur capable of converting all metals into its own sulphur, which possesses the energy of curing all diseases. This is our universal medicine against all the most deplorable diseases of the human body; therefore return infinite thanks to Almighty God for all the good things which he has bestowed upon us.

"9. In this great work of ours, two modes

of fermenting and projecting are wanting, without which the uninitiated will not easily follow our process. The mode of fermenting is as follows :—take of our sulphur above described one part, and project it upon three parts of very pure gold fused in a furnace; in a moment you will see the gold, by the force of the sulphur, converted into a red sulphur of an inferior quality to the first sulphur; take one part of this, and project it upon three parts of fused gold, the whole will be again converted into a sulphur, or a fusible mass; mixing one part of this with three parts of gold, you will have a malleable and extensive metal. If you find it so, well; if not, add another sulphur, and it will again pass into a sulphur. Now the sulphur will be sufficiently fermented, or our medicine will be brought into a metallic state.

"10. The mode of projecting is this :—take of the fermented sulphur one part, and project it upon ten parts of mercury heated in a crucible, and you will have a perfect metal; if its colour is not sufficiently deep, fuse it again, add more fermented sulphur, and thus it will acquire colour. If it become frangible, add a sufficient quantity of mercury, and it will be perfect.

"Thus, friend, you have a description of the universal medicine; not only for curing dis-

eases and prolonging life, but for transmuting the baser metals into gold. Give therefore thanks to Almighty God, who, taking pity on human calamities, has at last revealed this inestimable treasure, and made it known for the common benefit of all."

Such is one of the most easily understood of these wild vagaries and extravagant lucubrations, which, from the want of fixed principles, is commenced in ignorance, and terminated in absurdity. Next to the Philosopher's stone, the Alkahest, or universal solvent, was the object of alchymical research. The absurdity of this project was noticed by Lavoisier, who enquired, if the solvent were *universal*, what vessels would contain it.

In the earliest ages of the world, the manipulations of chemistry seem to have been necessary for the accommodation of man: thus we read in the Mosaic records,* "And Zillah, she also bore Tubal Cain, an instructor of every artificer in brass and iron." Again, in a time subsequent to that, we find chemistry standing on a more advanced ground; and that Moses was well acquainted with the art of reducing gold to powder, which he most probably obtained from the Egyptians.

* Gen. iv. 22.

The progress of chemistry during the dark ages appears to have been solely among individuals, and the rapidity of its advancement

A.M. 2076. must be looked for in their respective lives. Hermes Trismegistus, after whom chemistry has been called the Hermetic art,* is (if some of the writings attributed to him be authentic) the father of the alchymists: he certainly deals in the marvellous to a considerable extent, assuming a vast importance, and delivering his facienda only to the initiated. We are directed by him "to catch the flying bird, to drown it so that it fly no more;" by which is meant the fixation of quicksilver by combination with gold. It is, after amalgamation, to be subjected to action of "aqua regia," by which its soul will be dissipated, and it will be united to the red eagle, "muriate of gold." Geber has also been mentioned as a great alchymist, from whom, according to Dr. Johnson, the word Gibberish or Geberish is derived. His works were published A.D. 1520, at Strasburgh.

* Some say after the god Mercury.

A.D. 1130. Artephius published, in 1130, some alchymical tracts; and we are informed by Roger Bacon, that his life was miraculously protracted by medicinal agents to the age of 1025 years.

1193. In 1193, Albertus Magnus, or Albert Groot, a German, and a student of Padua; this man was an ardent admirer of chemistry, and after being created Bishop of Ratisbon, resigned the mitre for the calm repose of the cloister, where

Vide Vetera Monumenta, vol. vi. edited by Matthæus.

he continued an ardent prosecutor of science A.D. 1193.
till his death. Albertus supposes all metals to be compounded of sulphur and mercury. He mentions red lead, metallic arsenic, and liver of sulphur. Albertus had for a pupil St. Thomas Aquinas; and it is reported that when he had constructed the famous image which spoke articulately and answered questions, St. Thomas was annoyed by its chattering, and broke it to pieces.*

* At the end of the life of the next Alchymist, I shall say a few words more concerning this brazen man.

[A.D. 1214.] This year gave to the world a 1214.
man who is certainly the most astonishing example of powerful intellect that ever adorned the annals of a country. Roger Bacon was born at Ilchester in Somersetshire. He passed some part of his time in the study of divinity at Paris, and after his return became a member of the University of Oxford. "His writings," 1240.
says Dr. Thomson, "display a degree of knowledge and extent of thought scarcely credible, if we consider the time when he wrote, the darkest period of the dark ages. In his book, de Mirabile Potestate Artis et Naturæ, he begins by pointing out the absurdity of believing in magic, necromancing charms, or any of those similar opinions at that time universally prevalent." As an example of the force of perception with which this remarkable man thought, I will transcribe a few passages from this volume, which have never been equalled

A. D. 1240 by any writer of his time. The work I quote from, may be found in the collection of pamphlets, (No. 847), in the Kings' Library at the British Museum. It is entituled—

FRIER BACON.

HIS DISCOVERIES OF THE MIRACLES OF

ART, NATURE, AND MAGIC.

FAITHFULLY TRANSLATED OUT OF DR. DEE'S OWN COPY,*

BY T. M. AND NEVER BEFORE IN ENGLISH.

LONDON:

PRINTED FOR SIMON MILLER, AT THE STARRE, ST. PAUL'S CHURCH YARD.

* See Sir W. Scott's Demonology. p. 350.

"A Letter sent by Frier Roger Bacon to William of Paris, concerning both the secret operation of nature and art, and the utility of magick.

"CHAPTER I.

"*Of and against fictitious appearances, and the invocation of Spirits.*

"That I may carefully render you an answer to your desire, understand, nature is potent and admirable in all her working; yet art, using the advantage of nature as an instrument (experience tells us), is of greater efficacy than any natural activity.

"Whatsoever acts otherwise than by natural or artificial means, is not humane, but fictitious and deceitfull.

"We have many men, that, by the nimbleness and activity of body, diversification of sounds, exactness of instruments, darkness, or consent, make things seem to be present, which never were really existent in the course of nature. The world, as any judicious eye may see, groans under such bastard burdens. A juggler, by a handsome sleight of hand, will put a complete lie upon the very sight. The Pythonissæ, sometimes speaking from their bellies, otherwhile from the throat, than by the mouth, do create what voices they please, either speaking at hand, or far off, in such a manner as if a spirit discoursed with a man, and sometimes as if beasts bellowed, which is all easily discovered by privately laying hollow canes in the grasse or secret places, for so the voices of men are known from other creatures. A. D. 1240.

"When inanimate things are violently moved, either in the morning or evening twilight, expect no truth therein, but downright cheating and cozenage."

After this introduction, he speaks upon magic, and tells us, that "there is another more damnable practice, when men, despising the rules of philosophy, irrationally call up wicked spirits, supposing them of energy to satisfy their desires." He goes on to tell us of the folly of this practice, and concludes, "Without all question the way is incomparably

A. D. 1240. more easie to obtain any thing that is truly good for men, of God or good angels, than of wicked spirits. As for things which are incommodious for men, wicked spirits can no further yield assistance then they have permission."

To conclude these quotations, I cannot, I am sure, select a better than in the 2nd chapter of this same letter. Speaking of figures or charms, Roger Bacon says, "Physicians use figures or charms, not from any prevalency in them, but that the raising of the soul is of great efficacy in the curing of the body; and raising it from infirmity to health by joy and confidence, is done by charms."

Such is the style, the masterly style, in which this celebrated man writes. His Opus Majus, and his other works, however, claim for him a rank among the ornaments of his country, to which few have aspired. Considering this admirable man as by far the most worthy of notice of any whose names are illustrious in the arcana of alchymy, I cannot conclude these remarks without confirming what has been stated by a reference to contemporary authorities, as well as to modern writers on the subject.

Among the ancient attestations to the celebrity of Bacon, we have Jo. Selden de Diis. Syntag. I. p. 75. "That singular mathematician," says he,

speaking of Roger Bacon, "learned beyond what the age he lived in did ordinarily bring forth." Gabriel Powell:*—"Roger Bacon, an Englishman, a founded scholar of Merton College in Oxford, a very quick philosopher, and withal a very famous divine. He had an *incredible* knowledge in the mathematics, but without necromancy, (as John Balleus† doth report,) although he be defamed for it by many. Now this man, after he had sharply reproved the times wherein he lived—'these errours,' saith he, 'speak antichrist present.'(a) Nicholas IV. Pope of Rome, did condemn him, and he was by him imprisoned for many years together."‡

A. D. 1240.

* Book of Antichrist, p. 14.

† Who afterwards recanted.

‡ For ten years.

John Gerhard Vossius, in his book of the Four Popular Arts,§ is every where full of the praises of Roger Bacon:—"About this time Roger Bacon also flourished, an Englishman, and a monk of the order of Saint Francis;|| who, as he had dived into all arts and sciences, so also he writ many things of them. *He was a man both learned and subtil unto a miracle,* and did such wonderful things by the help of mathematics, that by such as were envious and ignorant, he was accused of diabolical magick before Clement the IV.¶ and for that detained in prison for some time."

§ Amsterdam edition, 1650.

|| A Cordelier monk; see Bayle's Dict. Article *Bacon*.

¶ Nicholas IV. according to Powell.

The same author quotes him in a multipli-

(a) Alluding to the immorality of the clergy.

A.D. 1240. city of places, to which the reader can refer, cap. 35, § 32, A.D. 1255; cap. 60, § 13, A.D. 1270; cap. 70, § 7, A.D. 1270.

Venema, in his Ecclesiastical History, says—"Rogerus Bacon, Franciscanus, et ornamentum Britanniæ suæ, clarus circa an. 1278, doctor mirabilis dictus in philosophicis ac chemicis usque eruditis, et mirabilium patrator, plus una vice propterea magiæ reus actus, etiam in carcerem conjectus, ipso Nicolao IV. mandante, pulveris quoque pyrei materiam et vim dicitur dilexisse, scripsit, præter epistolas prorsim editas, mathematica et chemica quæ prostant. Opus ejus Majus dictum, edidit Steph. Jebb, Doctor Medicinæ, hoc sec. cum erudita præfatione et notis."

So much for the authors who have, to the utmost of their power, lauded Roger Bacon in times gone by. Modern writers are no less sensible of the immense power of his gigantic mind. The first that I shall quote is Dr. Mosheim, (in a quotation from Dr. Jebb). He says, "Fuit tanta apparentia sapientiæ, nec tantum exercitium studii in tot facultatibus, in tot regionibus, sicut jam a quadraginta annis," &c.* Again, in the 9th section of this chapter, Dr. Mosheim says, "There were, however, at this time in Europe, several persons of superior genius and penetration, who, notwithstanding their veneration for Aristotle, thought the

* Eccl. Hist. p. 317. cent. xiii.

method of treating philosophy which his writings had introduced, dry, inelegant, and proper to confine and damp the efforts of the mind in the pursuit of truth, and who consequently were desirous of enlarging the sphere of science by new researches and new discoveries. At the head of these noble adventurers we may justly place Roger Bacon, a Franciscan Friar of the English nation, known by the name of the admirable Doctor, renowned on account of his important discoveries, and who, in the progress that he had made in natural philosophy, mathematics, chemistry, the mechanic arts, and the learned languages, soared far beyond the genius of his times." A.D. 1240.

Mr. Brande is the next authority that I shall quote. He says—"I know of no work that strikes one with more surprise and admiration than the Opus Majus of Roger Bacon. He stands alone like a beacon upon a waste. His expressions are perspicuous and comprehensive, such as betoken a rare and unclouded intellect; they are full of anticipations of the advantages likely to be derived from that mode of investigation insisted upon by his great successor, Chancellor Bacon."* Mr. Brande then gives us the following extract from Hallam's History of the Middle Ages: "Whether Lord Bacon ever read the Opus Majus, I know not; but it is singular that his favourite quaint

* Introd. Hist. of Chemistry, vol. i. p. 9.

A. D. 1240. expression, '*prærogativæ scientiarum*,' should be found in that work; and whoever reads the sixth part of that work, must be struck by it as the prototype in spirit of the Novum Organum."

About this period gunpowder appears either to have been discovered, or at least introduced into Europe. By some authors it has been attributed to Roger Bacon. He himself certainly intimates, that although possessed of the secret, he was not the discoverer. "For," says Bacon, "sounds like thunder, and coruscations like lightning, may be made in the air, and they may be rendered more horrible than those of nature herself." "In the Bible," he informs us, "the army of Gideon made use of this means, and so destroyed the Midianites." But this clearly demonstrates that he did himself advance no claim to the invention of the "humane discovery." That he was possessed of the secret, is manifested from the words "luru vopo vir con utriet," in connexion with the following sentence: "Mix together saltpetre, 'luru vopo vir con utriet,' and sulphur, and you will make thunder and lightning, if you know the method of mixing them." The words I have seen spelt rather differently,* "luru mone cap urbre," which is an exact anagram for "carbonum pulvere," the other ingredient

* In Mr. Brande's History.

of gunpowder.* Lord Bacon(*b*) was of opinion, that the thunder and lightning and magic, stated by the Macedonians to have been exhibited in Oxydrakes, when it was besieged by Alexander the Great, was nothing else than gunpowder.†

A. D. 1240.

* Thomson's History, p. 57.

Albertus Magnus, who was contemporary (or nearly so) with Roger Bacon, I have before briefly noticed; but as they have both been accused of the same practices of magic, in the formation of brazen heads and figures, imitating the articulations of the human voice, I have purposely delayed making these few remarks, in order to consider them in conjunction.

† In Speed's Chron. p. 44, §. 2, is a curious contradiction of Roger Bacon "For our learned countryman was certainly in error, who thinketh that Cæsar set up perspective glasses on the coast of France, and thus saw all the ports in England," &c.

The remarkable avidity with which the most incredulous romaunts were acceded to in the dark ages, prepares us in a great measure to expect absurdities; but in the life of Albertus Magnus, the mythology of alchymy arrives at its climax. A remarkable instance of this occurs in a book (published by Gerhard Block, "Hagæ-comitum," and written by Antonius Matthæus,) called the "Vetera Monumenta."‡

‡ The most complete history of the dark ages; it is written in Latin and Old Dutch, and is very often alluded to by Roscoe.

(*b*) A wish not to swell this work with apparently extraneous matter, has induced me to curtail the interesting history of this illustrious man. I regret this the less, as I intend to publish shortly a few pages exclusively connected with the history and works of Bacon.

A.D. 1240. In the fifth volume, (p. 540,) we are presented with the following fable:—

"A little while after this, the king set out to make his oblation to the church of the Three Kings at Cologne. When he was there, Albertus Magnus, Bishop of Ratisbon, very humbly asked the king that he would honour him by partaking of his hospitality at the Feast of the Epiphany. To this the king, hoping to see some strange thing, very readily agreed. His vows being performed, he proceeded, together with his family, to the residence of the bishop; the bishop received them magnificently, and lead the king from the dining-room to the garden, where the trees were arranged in wonderful beauty. The servants were present, and every thing necessary for conviviality. At the same time there was a severe winter, accompanied by intense cold, and the ground was covered with snow: the family of the king began to enquire if it was intended that the king should feast in this cold garden. And when the king and the bishops, and the other members of the retinue, were seated, each according to his rank waiting for the repast, on a sudden all the ice and the snow vanished, and in its place there was a mild summer, and the sun shone powerfully. And the grass grew of itself with alacrity from the earth; the trees blossomed wonderfully, and soon ter-

A. D. 1240.

minated in fruit fit to eat; and the birds of various kinds sang, by which means the guests were exceedingly delighted. After a time the heat became so powerful, that many of the company threw off part of their garments, and betook themselves to the shade of the trees. The attendants also brought to the table the various fruits. The king was exceedingly delighted upon seeing such wonderful things. At last, however, the servants who had ministered disappeared, and the birds vanished, together with the fruit of the trees; and the winter returning, all things were as before, so that every one hastened to the fire."

A man whose character was sufficiently high to impose such an ocular deception upon a monarch and his court, and to have that delusion ratified by the chronicles of his day, without the semblance of a doubt, is surely worthy of a niche in the Pantheon of alchymy.

The story, however, to which I refer more particularly, in comparing him with Roger Bacon, is that of the brazen head.* The following account of Albertus's brazen man, or Androis, as the thing was called, was taken from the translation of Naudé's Apologie, to which I must refer the curious reader for the various authorities. "Some persons," says the writer, "have maintained that brazen heads could be made, under the auspices, and during

* Martin Delrio, author of the Inquisitiones Magicæ, (a most useful and excellent work) has a few lines about this Androis of Albertus in which he informs us that the Psalmist alludes to such brazen figures, when he

A. D. 1240. says, "the idols of the heathen are silver and gold, the work of men's hands; they have eyes, but they see not, &c., neither speak they through their throat."—lib. i. ch. 4.

the time of certain constellations, which would answer any question proposed relative to affairs of life." It is reported that Polydore Vergil, Pope Sylvester, Robert of Lincoln, and Roger Bacon, possessed such heads; but to Albertus Magnus the palm was given, inasmuch as he had constructed a whole man of this nature—a labour that took him thirty years in its accomplishment, owing to necessary lapse of time occurring between the favourable planetary conjunctions. This is called the Androis of Albertus Magnus.

The legend with regard to the brazen head of Bacon, is rarely told the same by the various authors who mention it. The most ancient that I have seen is this:—Friar Roger Bacon and Thomas Bungay had, by wonderful skill, constructed a head, after seven years' incessant attention and study, which was to answer them the question—if it were possible to surround England by a wall or rampart to protect it? About the time it was expected the head would reply, the two friars sat up for three whole weeks, till at last, being wearied, they betook themselves to rest, after having appointed a servant to watch the head carefully, and to wake them immediately it spoke. A short time after the head exclaimed, "Time is," which the servant did not think sufficient to justify him in waking his master. A few

minutes having elapsed, the head again spoke, exclaiming, "Time was." The change of tense did not procure for the speaker a more reverential audit than before, when, in the space of half an hour after this second warning, the head exclaimed, "Time is past," at the same time falling to the ground and dashing itself to pieces, the fall being accompanied with frightful sights, together with thunder and lightning. This is the story, or legend, of the brazen head. A.D. 1240.

It does not appear to me necessary to argue out this case as to the evidence on which it rests; but in order to satisfy the antiquarian, I may give the explanation of Naudé, who seems to consider it supported sufficiently by history to deserve a reply. Naudé says,* he thinks it possible that a machine might have been so constructed as to articulate in intelligible sounds, and quotes, in support or justification of his opinion, the passage in which Cassiodorus,† speaking of the machines of Boethius, informs us, "that they low like an ox, bellow like a bull, sing like a bird, and lastly, emit a sweet sound from the brass not to be distinguished from one's own voice."

* Apologie, p. 566.

† Lib. i. Epist. varior.

I must here close this subject, and commence with another of the alchymical fathers, by some supposed to have been a pupil of Roger Bacon.

A.D. 1240. Raymond Lully was also a Friar Minorite. This man seems to imagine that his fame depended more upon the quantity than the quality of his writings; he accordingly, in the words of Dr. Arnold with regard to Poppo, "inflicted his prolixity, and bestowed his tediousness upon his readers, without all bounds of moderation." Like his predecessors, he maintained all metals to be compounds of sulphur (or rather a something not known, which he denominated sulphur,) and mercury. He was acquainted with spirits of wine, and also with the means of abstracting water from the weaker by means of potassa, in order to rectify it. He was the first who obtained a distilled oil from rosemary. It is reported that he was stoned to death for preaching the gospel, a thing by no means probable, as his desire to impose upon his contemporaries in alchymy, leads us to conclude that he was much more likely to have received this punishment as a reward for his charlatanry and quackery, rather than for preaching the gospel.

1245. Arnoldus de Villa Nova, a pupil of Casamila, made his appearance about this time; a man of greater repute as a physician and astrologer than as an alchymist. He foretold the destruction of the world in 1335. His works were published in 1505.

1290. John Isaac Hollandus and his brother wrote

about this period. They promulgated the opinion that metals were composed of salt, sulphur, and mercury. A.D. 1290.

Another of the voluminous writers appears about this time to have flourished — Basil Valentine, one of the most remarkable men in the annals of alchymy. He follows the opinions of the former alchymist, Hollandus, with regard to the metals. Dr. Thomson says,* "The only one of his works I have read with care, is Kirkringius's translation of the Currus Triumphalis Antimonii. It is an excellent book, written with clearness and precision, and contains every thing respecting antimony that was known before 1800.

* Hist. p. 46.

A curious tale has been started respecting the origin of the word antimony. It is said, that immediately Valentine discovered one of the salts of antimony, (or oxides—I forget which) he tried its effects upon some pigs belonging to the monastery; it purged them violently for a time, but afterwards they fattened with astonishing rapidity. By an inference, he considered analogically drawn, he concluded that it must produce the same felicitous effect upon the lean members of the monastery; but in this he lamentably failed, thirty-five perishing in one night. As if to perpetuate so glorious a victory, he named the metal "anti-moine."

A. D. 1290. I have now only to mention the last of alchymists. Theophrastus Bombastus Paracelsus, as he called himself, (Philip Hochener being his real name,) must always deserve the gratitude of the world as the discoverer of calomel. Dr. Paris has remarked, "that we are indebted to a savage and a madman for one of our most valuable remedial agents, an untutored Indian being the discoverer of bark, and Paracelsus of calomel." * With all due deference to so high an authority, I cannot but remark that the love of antithesis predominates in this passage more than that of historical truth. That Paracelsus was guilty of some extraordinary actions, it cannot be denied; but that these amounted to insanity, is very questionable. If we refer to the history of science in general, we shall find that the imputation of insanity has not been limited to Paracelsus. We shall find that it was the watchword of a set of individuals whom interested ignorance prompted to set themselves in array against every discovery; and that their general reply to every thing which tended to endanger their private emolument, was similar to that of the Ephesians to St. Paul—"Great is Diana of the Ephesians." If this was not sufficient to overawe the community, and stifle all attempts at carrying on the inquiry, then the war-whoop was raised, and the unfortunate individual was

* Life of Sir H. Davy.

denounced as a madman. Harvey, the discoverer of the circulation of the blood, was condemned to lead a life of wretchedness, to close his days in misery and want. This was the case, more or less, with every philosopher who attempted to dispel the gloom that pervaded Europe during the dark ages. A.D. 1290.

The writings of Paracelsus are affectedly bombastic; but what are we to expect from a man hunted down by every body—a man whom the justice of public functionaries refused to protect—a man who was considered the common enemy of mankind? If it were madness in Paracelsus to search for the Philosopher's stone, or to endeavour to make the universal elixir, what must we think of a writer,* who not long ago delivered, in the pages of the Philosophical Magazine,† the following rhodomontade: "In the nineteenth century the transmutation of metals will be generally known and practised. Every chemist and every artist will make gold; kitchen utensils will be of silver and even gold, which will contribute more than anything else to prolong life, poisoned at present with the oxides of copper, lead, and iron, which we daily swallow with our food." He next tells us, that a chemical friend writes to him,‡ "The metals seem to be composite bodies, which nature is perpetually preparing; and it may be reserved for the

* Vide D'Israeli, vol. ii. p. 54.

† Vol. vii. 383.

‡ Dr. Girtanner of Gottingen, is the author; who the friend is, we are not informed.

A. D. 1290. future researches of science to trace, perhaps to imitate, some of these curious operations." "Sir Humphry Davy told me, (says Mr. D'Israeli) that he did not consider this undiscovered art an impossible thing, but which, should it ever be discovered, would be certainly useless."

We have now finished the history of the alchymists, who shine in the middle ages like so many stars on a dark night; whose golden dreams excite pity and admiration. Their lives of enthusiastic devotion, their love for the ideal, their airy conceptions, keep them apart from the world; they seemed to touch our sphere, not to belong to it. Yet such is the happiness in following even what we know to be a delusion, that we feel inclined, while perusing the futile attempts of alchymy, clothed in the expressive language of the "Mysteries of the Night," to say, "Stay, beautiful vision, stay. . . . But the vanishing spirit heard me not; receding into the darkness, like that orb whose track she seems to follow, her form lessens away till she is seen no more."*

* Epicurean p. 115.

SECTION II.

OF SIR KENELM DIGBY, VAN HELMONT, AND THE CHEMISTS OF THE 17TH CENTURY.

THE line between Modern Chemistry, historically considered, and the chemistry of days gone by, is so fine, that it is difficult to perceive where it is with the greatest propriety drawn. It may be compared to the golden belt which surrounded the White Lady of Avenel, diminishing as the house of Avenel, until at last, the time being arrived when A. D. 1290.

> "The knot of fate at length is tied,
> The churl is lord, the maid is bride,"*

it had dwindled down to the fineness of a thread of gossamer.

So it is with the visions of alchymy: the nearer that they approached to the system of inductive reasoning, the line of the marvellous decreased in magnitude; till at last, when the alliance was made between alchymy and

* Monastery, Sir W. Scott.

A. D. 1290. Bacon, the line had dwindled to the fine thread, and the poesy of the dark ages was lost in the cold calculations of the Baconian era. The first of the ancient chemists who began this reducing change, was Van Helmont. There was one, however, who lived about this time, whose name it would be a heresy to pass by unnoticed—this was Sir Kenelm Digby.

Sir Kenelm Digby was a member of Worcester College, Oxford. No man has had a greater variety of epithets bestowed upon him than this celebrated man; after all, his chief fault seems to have been, remarkable credulity. I shall make one quotation from his works, and refer the reader for a more lengthened account of him to Elias Ashmole. In a work entituled "The Cure of Wounds by the Powder of Sympathy,"* in which Sir Kenelm attempts to prove that wounds may be cured by an application of medicaments to the weapon, we have the following story:—

* Pub. Lond. 1669, by John Williams.

"Mr. James Howell coming by, by chance, as two of his best friends were fighting a duel, did his endeavour to part them; and putting himself between them, seized with his left hand upon the hilt of one of the combatants, while with his right hand he laid hold of the blade of the other. They being transported with fury one against the other, struggled to rid themselves of the hindrance their friend

made, that they should not kill one another; A.D. 1651. and one of them, roughly drawing the blade of his sword, cut to the very bone the nerves and muscles of Mr. Howell's hand; and then the other, disengaging his hilt, gave a cross blow on his adversary's head, which glanced toward his friend; who, heaving up his hand to save the blow, was wounded in the back of his hand, as he had been before within. It seems some strange constellation reigned then against him, that he should lose so much blood by parting two such dear friends, who, had they been themselves, would have hazarded both their lives to have preserved his: but this involuntary effusion of blood by them, prevented that which they should have drawn one from the other. For they, seeing Mr. Howell's face besmeared with blood by heaving up his wounded hand, both ran to embrace him: and having searched his hurts, they bound up his hand with one of his garters, to close the veins which were cut and bled abundantly. They brought him home and sent for a chirurgeon; but this being heard at court, the king sent one of his own chirurgeons, for His Majesty much affected the said Mr. Howell.

"It was my chance to be lodged hard by him; and four or five days after, as I was making myself ready, he came to my house and prayed me to view his wounds: 'for I

A. D. 1651. understand,' said he, 'that you have extraordinary remedies upon such occasions; and my chirurgeons apprehend some fear that it may grow to a gangrene, and so the hand must be cut off.' In effect, his countenance discovered that he was in much pain, which he said was insupportable in regard to the extreme inflammation. I told him that I would willingly serve him; but if haply he knew the manner how I would cure him, without touching or seeing him, it may be he would not expose himself to my manner of curing; because he would think it, peradventure, either ineffectual or superstitious. He replied, 'The wonderful things which many have related to me of your way of medicament, makes me nothing doubt of its efficacy; and all that I have to say to you is comprehended in the Spanish proverb, 'Hagase el milagro, y hagalo, Mahoma:' 'Let the miracle be done, though Mahomet do it.'

"I asked him, then, for any thing that had the blood upon it; so he presently sent for his garter, wherewith his hand was first bound: and as I called for a bason of water, as if I would wash my hands, I took a handful of powder of vitriol, which I had in my study, and presently dissolved it. As soon as the bloody garter was brought me, I put it in the bason, observing the while what Mr. Howell did, who stood talking with a gentleman in a corner of

my chamber, not regarding at all what I was doing; but he started suddenly as if he had found some strange alteration in himself. I asked him what he ailed. 'I know not what ails me,' said he, 'but I find that I feel no more pain: methinks a pleasing kind of freshness, as it were a wet cold napkin spread itself over my hand, which hath taken away the inflammation that tormented me before.' I replied, 'Since then you feel already so good an effect of my medicament, I advise you to cast away all your plasters; only keep the wound clean, and in a moderate temper betwixt heat and cold.' After dinner I took the garter out of the water, and put it to dry before a great fire. It was scarce dry when Mr. Howell's servant came running to tell me that his master felt as much burning as ever he had done, if not more; for the heat was such as if his hand were betwixt coals of fire. I answered, 'that although that had happened at present, yet he should find ease in a short time;' for I knew the reason of this new accident, and I would provide accordingly, so that his master should be free from that inflammation, it may be, before he should possibly return to him; but, in case he found no ease, I wished him to come presently back again; if not, he might forbear coming. Away he went, and at the instant I again put the A. D. 1651.

A.D. 1651. garter into the water; thereupon, he found his master without any pain at all. To be brief, there was no sense of pain afterwards; but within five or six days the wounds were cicatriced and entirely healed. This relation is attested (says the writer) by His Majesty King James and Lord Bacon."

The work from which this narrative has been selected, is generally bound up in a volume, together with another by the same author, "Digby on Bodies." The whole work abounds with originality, and at the 153rd page he enters into a long discussion upon light, for the purpose of proving that it comes off in straight lines from the sun, and that it is a material body.

Van Helmont is the next to whom we shall direct our attention; he is the father of a sect of chemists called by Dr. Thomson, the Iatro-chemists, a race of chemical centaurs, half physician, half chemist, who endeavoured to practise medicine upon principles purely chemical, and who account for the various secretions of the human body, and the changes to which it is liable, by opinions bordering upon the absurd, and what is worse, absurd without any admixture of ingenuity. Van Helmont himself, whether we regard him as a philosopher or a Christian, is equally worthy of our reverence and imitation. He was born

in 1577, and studied divinity till the age of seventeen. Martin Delrio, (whom I have already quoted as the author of the "Institutiones Magicæ,") taught him magic; but Van Helmont was dissatisfied. A.D. 1651.

St. Thomas à Kempis having accidentally fallen into his hands, he was so struck with the dignified humility of our Saviour, that he determined upon imitating him; and as a practical proof of his theoretic sincerity, he gave up possession of his domains, (the lordship of Merode, and some other places,) and left them to his sister. It is said, that a spirit always accompanied and advised him; and that his own soul once appeared to him in the figure of resplendent crystal. For his opinions I refer to that excellent work, "The History of Chemistry, by Dr. Thomson."*

* Vide Thomson, p. 180.

The sect professing the principles of Van Helmont,(*c*) have about as much relation to him, as the Epicureans had to Epicurus some few years after his death. The limitations of my essay will not allow me to enlarge more

(*c*) Mosheim (cent. xvi.) traces the opinions of Van Helmont to the Rosicrucians, who flourished about this period; but there is so much free-masonry about this sect, and consequently so many different speculations upon their opinions, that we know not what they believed. Vide also Wood's Hist. Antiq. Oxon. and Jacob Behmen, for the opinions of Van Helmont and the Rosicrucians.

A.D.1651. upon this point than is absolutely necessary; and therefore, passing over Silvius, Riolan, Dr. Willis, Dr. Croone, and others, I shall say a few words concerning our celebrated countryman Boyle.

1660. Robert Boyle was born at Youghall, Jan. 25th, 1627. He was of a noble family, and was educated first at Eton, and finally at Oxford. It was during his residence at Oxford that he originated the "Philosophical College," which was afterwards transferred to London, and by King Charles the Second incorporated under the name of the "Royal Society."* Mr. Boyle was the first who attempted to reduce to reason the speculative notions of the Iatro-chemists. He is particularly famous for the introduction into Britain of the air-pump and thermometer.

* Dr. Thomson, p. 204.

Chemistry continued at this period progressively improving. Philosophers seemed to be more eager for facts than formerly, and less so for theoretic opinions. The first who absolutely reduced chemistry to any form was Boerhaave, a man celebrated for his attainments in medicine and botany, as well as in chemistry: his attempt was to methodize the facts presented to him, and to satisfy
1690. himself as to what was proved, and what was doubtful in science. He was the pupil of Dr. Pitcairne, a physician of considerable

eminence, more especially so for his vigorous opposition to the Iatro-chemists. Boerhaave occupied a considerable portion of his time in a laborious course of experiments to prove the attempts of alchymists to fix mercury absurd. A. D. 1690.

About the same era flourished Glauber, Kunkel, Lemery, and others, of whom certainly Kunkel was the most celebrated. The discovery of phosphorus has been imputed to him, although, from more mature inquiry, it appears to belong to Brandt. Homberg was also contemporary wth the three above-named chemists. He is remarkable for a pyrophorus, of which I shall say more in the sequel.

Such was the state of chemistry towards the close of the 17th century; the rapid improvement is to be attributed to the works of that great man Lord Bacon. In the commencement of the century, he had pointed out the necessity of chemical investigations for promoting the comforts of life; but here he left it. He proposed no principles exclusively for chemistry; but having pointed out the way, predicted that, if properly cultivated with due attention to facts, the most important advantages would result. How amply has the prediction been verified! We have seen in the commencement of this era, science labouring under the greatest disadvantages; the cultivation of chemistry was followed by an

A. D. 1690. imputation of dealings with the devil, or of insanity. The prosecutors were in these cases constituted both judge and jury, the result, of course, fatal to the progress of philosophy; added to this, the continual disagreement between the nations of the continent among themselves, and also with England, rendered any interchange of opinions between philosophers almost impossible. Nor was this all: the few who were willing to devote themselves to the advancement of science, found, for the most part, their particular country so torn with civil convulsions, as to render them unable to attain the calm of mind absolutely necessary for study:

> "The doctrine to-day which was loyalty sound,
> To-morrow might bring them a halter."*

* Burns.

As an example, I have already cited Roger Bacon, a man imprisoned for ten years by reason of an imputation utterly groundless. Upon following up the history of our own country, witness the few eminent men in the reign of that libidinous tyrant King Henry the Eighth; the little science at that time in England being with the monks, when their splendid edifices were seized upon, with all their appurtenances, to glut the rapacity of a monster; when those places which were once the abode of sanctity, and the places of resort for the

needy and the poor, became the seat of perjury and the reward of crime. What was the inevitable consequence? The overthrow of religion, and the destruction of philosophy.(*d*) A.D. 1690.

Under the reigns of Elizabeth and Mary, the same difficulties prevailed. When the Stuarts ascended the throne, then learning once more was courted, and many eminent men sprung up, whose names are an honour to the annals of their country. But this was not for a long continuance: the mildest monarch of that ill-fated house is brought to a pretended trial,

(*d*) Fearing the words above may convey a meaning quite foreign to my intention, I here repeat, that the overthrow of learning was an inevitable consequence of the destruction of those religious houses where alone it flourished. And in speaking against Henry the Eighth as the instrument of evil in the desolation of the church, and the mal-appropriation of her property, I by no means wish for a moment to imply that the consequences of this change have not been beneficial to England. Henry overthrew the church to gratify his vices; Calvin sanctioned the murder of Servetus; and Knox gained for himself the eternal execrations of posterity for his brutal demeanour to Mary Queen of Scots. But, in the words of Pope, we must consider

"All partial evil universal good."

The Deity, in order that man should not have whereof to glory in the commencement of the Reformation, allowed the crimes of these men to exist; but, overruling the evil, brought forth good. For a more explicit statement, the reader is referred to Hume's History of England, chap. 35, reign of Edward the Sixth

A. D. 1690. and, by a band of remorseless ruffians, equally hateful to God and man, is condemned to the block. During the usurpation of the assassin, scarcely a man of letters could appear, unless indeed one who could applaud the deed of regicide, and add the title of blasphemer to his other qualifications. The Puritans, zealous in the work they had began, were not content until every trace of the literary renown of England was destroyed; the churches were plundered, the altars desecrated, the old and valuable manuscripts committed to the flames, and anarchy and confusion every where prevailed.

When Oliver made his exit, King Charles the Second—whatever his character for profligacy, which is not defensible—was still an encourager of learning. He founded the Royal Society, and contributed much to the revival of the literature of the country; although the abominable licentiousness of the times was found equally deleterious to the interests of science, as the former era of puritanical cant.

In the reign of James the Second we may boast of a Boyle and a Newton. "In Newton," says David Hume,* "this island may boast of having produced the greatest and rarest genius that ever rose for the ornament and instruction of the species. Cautious in admitting no principles but such as were founded on expe-

* Vol. x. 12mo. edition, p. 215.

riment; but resolute to adopt every such principle, however new or unusual: from modesty, ignorant of his superiority over the rest of mankind, and thence less careful to accommodate his reasonings to common apprehensions; more anxious to merit, than eager to acquire fame—he was, from these causes, long unknown to the world; but his reputation at last broke out with a lustre which scarcely any writer, during his own lifetime, had ever before attained." A.D. 1690.

The reign of William the Third gave to the world a number of eminent men exceeding that of his predecessors; but this we must attribute more to the alteration in the times, than to the patronage of a monarch whose character has been handed down by our ablest historian as "a fatalist in religion, indefatigable in war, enterprising in politics, *dead* to all the warm and generous emotions of the human heart; a cold relation, an indifferent husband, an ungracious prince, and an imperious sovereign."

With the death of William closes the seventeenth century, upon which we may congratulate ourselves that, notwithstanding all its disadvantages, we, by a tremendous superiority, excel our continental neighbours.

SECTION III.

THE HISTORY OF CHEMISTRY, FROM THE CLOSE OF THE 17TH CENTURY TO THE PRESENT TIME.

A. D. 1700. The eighteenth century commences under auspices of no very favourable aspect. The increase of scepticism appears to have been most alarming, especially among literary men. Of a circumstance, apparently so favourable to his cause, the infidel has availed himself to a very great extent: and by asserting a great deal, and proving but a very little, it was but too evident that an opinion gained ground very prejudicial to the cultivation of science. It was advanced, that the promotion of the interests of scientific attainments was accompanied by an equal increase of infidelity. Now, although the names of Boerhaave and Newton are in themselves sufficient to refute so gross a fabrication, it may perhaps be deemed advisable to meet the adversary on his own grounds, and to see if the conclusion has been fairly drawn.

I shall not introduce a variety of names which have been, by the most tortuous system of misinterpretation, enlisted by the sceptic to form part of his phalanx, because it may be proved that many names have been conceded to that side of the question without any just grounds. It was too much the practice, a few years ago, to meet the arguments of an antagonist by the cry of infidel, atheist, and heretic; but "this sort of ecclesiastical artillery has fallen into disuse, being considered more noisy than destructive."* But supposing for an instant that the majority of learned men were arranged on the side of infidelity, no logical conclusion could possibly be drawn from such premises until it had been ascertained upon what grounds their infidelity was founded. In most instances where the unfortunate coincidence has been truly found, the individual has given his attention to one subject alone, and has entirely omitted all consideration of any other. But mark the contrast: take a man who has given his attention to science, and who at the same time has not neglected the weightier matters of religion, and we shall find that the farther he has advanced, the more careful has he been to render his knowledge subservient to the interests of religion. Van Helmont studied chemistry in order to imitate our Saviour in doing good to the poor.† Boerhaave was not more

A.D. 1700.

* Lawrence's Lectures on Man.

† Vide Dr. Thomson.

A. D. 1700. remarkable for his immense attainments, than he was for his religious and charitable life; so much so, that Dr. Samuel Johnson proposed him in this respect as an example for his own imitation. And I am sure that the mention of Sir Isaac Newton is enough, without any eulogium of mine.

Having then stated thus much, I shall not deem it necessary to refute the charges brought against each of those individually whose works I shall have occasion to notice.

The first chemists whose works adorn the eighteenth century, are Beecher and Stahl—names so intimately connected, that they may be considered in conjunction. The most noted theory of these two celebrated men has been called the "Phlogistic theory." It was invented by Beecher, but considerably modified and improved by Stahl. The Phlogistic theory asserted, e limine, that all combustible bodies were compounds: and that the composition was the elements of which the body was formed, together with an additional one termed "phlogiston." Almost all the facts then known agreed with the hypothesis; and it was made a part of the theory, that phlogiston was liberated during the process of combustion. The metaphysical notions prevalent about this period, to a certain extent, infected chemistry, and the science was by these philosophers considerably impaired.

Each metal was considered to be a compound of a calx (an individual calx differing with the different metals) and phlogiston: these calces united with phlogiston indefinitely. But the only definition given of phlogiston agreeable to Stahl, considered it an earthy substance, composed of particles extremely rare, and very much predisposed to be set in motion with great velocity. The metaphysical chemists, however, by way of reconciling the fact, that metals, upon being converted into calces, increased in weight, with the phlogistic theory, declared phlogiston to be utterly destitute of weight, and endowed with a principle of levity. The fact, however, had been noticed; and as it was deemed impossible that an immaterial principle could have an attraction for a material substance, the phlogistic theory was in fact overturned. Such, however, is the force of prejudice, that chemists were not wanting to reconcile, by the most plausible arguments, this discrepancy—a proof of the words of one of our most beautiful poets— A.D. 1700.

> "The babe may cease to think that it can play
> With heaven's rainbow; alchymists may doubt
> Their shining gold that crucibles give out;
> But faith, fanatic faith, once wedded fast
> To some dear falsehood, hugs it to the last."

The opinion that chemists entertained of this anomalous nonentity may be seen from

A. D. 1700. the words of Bishop Watson, in his Chemical Essays.* "Besides an elementary fire which chemists conceive to be everywhere uniformly diffused, they are of opinion that fire enters, in different proportions, into the composition of all vegetable and animal, as well as most mineral substances; and in that compacted, condensed, fixed state, it has been denominated phlogiston. Of itself, in its natural state of uncombined expansion, fire is not esteemed capable of shining or burning; but when chemically conjoined with the other principles of bodies, it is that alone which conceives or continues those motions by which bodies are made to shine, burn, or to consume away. All bodies are more or less susceptible of combustion, according to the quantity of this principle which enters into their composition, or the degrees of force with which it adheres to them. Notwithstanding all I can say upon the subject, I am sensible the reader will still be ready to ask, What is phlogiston? You do not surely expect that chemistry should be able to present you with a handful of phlogiston, separated from an inflammable body. You may just as reasonably demand a handful of magnetism, gravity, or electricity, to be extracted from a magnetic, weighty, or electric body. There are objects in nature which cannot otherwise become the objects of sense, but by the effects

* Vol. iii. p. 167.

they produce; and of this kind is phlogiston." A.D. 1700.

This was the style of abstract reasoning to which the supporters of the hypothesis of Stahl were necessitated to resort. The opinions were advanced upon isolated facts, and supported by abstract deductions, so that before the death of Stahl, a number of theories were circulated professedly after him, which had nothing in them of the original hypothesis but the word "phlogiston." So that the task was quite Herculean, to crush a theory which, like the fabled Hydra, no sooner lost one of its hundred heads, than others immediately sprang up in its place; thus, by continued modifications, the phlogistic theory occupied the whole century.

Hitherto we have considered chemistry as confined to a few individuals, and cultivated by them under pains and penalties; but in the sequel we shall take a more extensive view of the subject, and, noticing the most important discoveries, treat of chemistry as a general science, supported not by the chimerical fancies of a lively imagination, but subsisting on the broad basis of mathematical demonstration. I am aware that in the concluding pages of this Introduction, much will be omitted that should have been inserted, and much inserted that would have been with greater propriety

A. D. 1700. omitted. My intention is, to notice the improvements that have been made in chemical
1717. science during the eighteenth century.

In this year (1717,) the founder of Pneumatic chemistry, Dr. Stephen Hales, published his Essays. He first noticed the fact, that iron filings and sulphuric acid produced little or no action; but that upon the addition of water a gaseous product was formed: this, however, he deemed unworthy of examination. A number of curious experiments were performed by him, but by an unfortunate haste he rarely
1718. examined into their meaning.

The year 1718 is remarkable for presenting the world with the "Tables of Affinity of Geoffroy," a most excellent production for the
1722. extension of chemical science.

Reaumur is a name that can hardly be mentioned without a catalogue of valuable experiments performed by him. He made France acquainted with the art of converting iron into steel, in a work published this year; the nation, previous to the publication of this volume, deriving all their supplies of this article from Germany. He recommends for the formation of steel—

4 parts of soot.
2 parts of charcoal powder.
2 parts of wood ashes.
1½ part of common salt.

The iron bars were to be enveloped in this mixture, and kept at a red heat till converted into steel. A. D. 1722.

Dr. Black, in 1756, published his first work on the properties of magnesia, quicklime, and some other substances. To Dr. Black, chemistry is indebted for some of the most accurate experiments, and a theory, without which it would be impossible to solve a variety of problems—this is the theory of latent heat. The only instrument we have that is capable of affording us any notion of heat, is the thermometer: but it must be remembered that the thermometer is merely an index of the relative temperature of one body compared with another; and that it by no means gives us an idea of the exact quantity of heat contained by the respective substances. Thus the mercury in the thermometer rises upon the application of a heated body, and this gives us the temperature of that body as marked by the scale of degrees; but this fact implies nothing more than the actual impression made upon the liquid in the thermometer, and from it we can deduce no proof of the capacity of the substance in question for heat, or the actual quantity present. All we obtain from the instrument is, how far the temperature of one body is exceeded by the temperature of another. As an example, if two vessels of different capa- 1756.

A. D. 1756. cities, one capable of containing a pint, the other two pints of water, be filled from the same source, the thermometer will express the same temperature; if it stands at 40° in the pint, it will stand at the same in the other: whereas it is self-evident that the quantity of heat must differ, inasmuch as it would take much longer to raise the larger quantity to the boiling point than it would the smaller. From this we perceive that the quantity of heat is different, and that the capacity for heat increases as the same body increases in size. "If equal quantities of water are mixed together, one portion being at 100°, and the other at 50°, the temperature of the mixture will be the arithmetical mean 75°; that is, the 25° lost by the warm water, will exactly suffice to heat the cold water by the same number of degrees. It is hence inferred, that equal weights or measures of water, at the same temperature, contain equal quantities of heat; and the same is found to be true of other bodies. But if equal weights or equal bodies of *different* substances are employed, the result will be different. Thus, if a pint of mercury at 100° be mixed with a pint of water at 40°, the mixture will have a temperature of 60°; so that the 40° lost by the former, heated the latter by 20° only; and when, reversing the experiment, the water is at 100°,

and the mercury at 40°, the mixture will be at 80°, the 20° lost by the former causing a rise of 40° in the latter."* A. D. 1756.

From these facts, and some others detailed in the excellent volume † from which this extract has been made, Dr. Black made the following deductions:—That heat is present in bodies in two opposite states: in one it is in a state of chemical combination, which he termed latent or concealed; in the other, free and uncombined, producing sensible changes upon the thermometer by the facility of its transmission from one substance to another. But as this is a theory as yet not perfectly demonstrated, Dr. Turner suggests, that for the sake of philosophical accuracy, the terms "sensible and insensible heat," should be used instead of "latent or uncombined."

* Dr. Turner's Elements, 5th edit. p. 45.

† p. 46.

The year 1770 presents us with the first paper of a most eminent chemist of the Swedish school—Charles William Scheele, a man rising from an occupation laborious and unthankful, to a lofty pinnacle of fame. Notwithstanding the arduous duties of his station, an apprentice to an apothecary, he prosecuted the study of chemistry with the greatest ardour; performing his experiments in the night, as his time in the day was fully occupied in the duties of his office. It is affirmed, on the authority of Crell, that Scheele was invited to England with a 1770.

A.D. 1770. pension of £300 a year, but that a change in the ministry put a stop to the overtures for a time. The invitation was repeated in 1786. Dr. Thomson* considers the whole as a very doubtful statement; and these doubts were confirmed by the result of his inquiries, made during the lifetime of Sir Joseph Banks, Mr. Cavendish, and Mr. Kirwan, who were totally ignorant of any such negociation. "I am utterly at a loss to conceive," says Dr. T. "what one individual, in any of the ministries of George the Third, was either acquainted with the science of chemistry, or at all interested in its progress. They were all so intent in accomplishing their own objects, or those of their sovereign, that they had neither time nor inclination to think of science, and certainly no money to devote to any of its votaries. What minister in Great Britain ever attempted to cherish the sciences, or to reward those who cultivate them with success? If we except Mr. Montague, who procured the place of Master of the Mint for Sir Isaac Newton, I know of no one. While in every other nation of Europe science is directly promoted, and considerable sums are appropriated for its cultivation, and for the support of a certain number of individuals who have shown themselves capable of extending its boundaries, not a single farthing has been devoted to any

* History of Chemistry, vol. i. p. 61.

such purpose in Great Britain. Science has been left entirely to itself, and whatever has been done by way of promoting it, has been performed by the unaided exertions of private individuals."(*e*) A. D. 1770.

Scheele's paper to which I have alluded, was published in 1770: it contains a method for obtaining pure tartaric acid. In the following year, he wrote another on fluoric acid, the experiments being made while Scheele was in an apothecary's shop. 1771.

Dr. Priestley, on the 17th of August in the year 1771, performed the following experiment, which I believe was the first that led to the discovery of oxygen gas, three years afterwards. "Having allowed a candle to burn in air until the air was incapable of supporting combustion, he introduced a sprig of mint, which he kept in it for some days; and on the 27th, he found that the air was sufficiently pure to support another candle burning in it for some time."*

In the same year, Lavoisier—a name scarcely to be mentioned without feelings of interest

* Brande, p. 100.

(*e*) Since the publication of the work from which this has been taken, a man to whom England and the world are indebted for many valuable improvements in science, has been presented, by a *liberal* administration, with a pension of £50 a year—a sum at which a favourite lacquey would certainly look with contempt.

A.D. 1771. as it regards his valuable life or his inauspicious death—published his paper on the "Steam-
1772. engine;" and in the following year, in the Memoirs of the Academy, is inserted a very elaborate paper on the "Combustion of the Diamond." Newton had suspected its combustibility from its great refractive power. Lavoisier discovered the result of its combustion to be carbonic acid gas.

1773. Bergman, in 1773, published his paper on the "Shapes of Crystals," in which he demonstrates, that from a very simple primary form of a mineral, other forms may be produced bearing no resemblance to the primary form. This paper is of importance, inasmuch as it is the foundation of M. Haüy's theory of Crystallization.

1774. This year, 1774, is certainly one of the most important in the history of chemistry. The fame of Dr. Priestley rests chiefly upon his discovery of oxygen gas during this year. He named it "dephlogisticated air," supposing it to be air deprived of its phlogiston. Dr. Priestley first obtained the gas from red precipitate of mercury, which was exposed to the agency of heat by means of a very powerful lens. I shall not say more of this element at present, as I must advert to it again in a few pages.

The history of the discoverer of oxygen is a blot upon the annals of England. Although

the spirit of dissent from an established church A.D. 1774. should be looked upon as a crime of no trifling import, yet it behoves those who take upon them to execute the vengeance of the Deity upon an offender for this crime, to remember that religious persecution is certainly not allowed by the canons of a Christian church.

"To suppose," says Dr. Thomson, "that Priestley was in the least formidable to so powerful a body as the Church of England, backed as it was by the aristocracy, by the ministry, and by the opinions of the people, is perfectly ridiculous." Upon what ground then is the persecution to be explained? Every heterodox notion of Priestley's had been answered, ably and satisfactorily, by Dr. Horsley, and that excellent prelate was more than a match for a dozen Dr. Priestleys in theological discussion. Yet the usual artillery was put into play: the unfortunate man was held up as a wretch unfit to live; the names of infidel, heretic, schismatic, and so on, were lavished on him with the profuse liberality of indiscriminating ignorance; and Dr. Priestley was expelled the country. He was one of those men whose opinions, at first sight, take up without premeditation the weaker side, and who, by a very common process of self-persuasion, fancy that they have proved those very opinions which they formerly adopted for the sake of

A.D. 1774. argument. These men think it a merit to be a martyr in any cause; and I am convinced, that if Dr. Priestley had lived in the times of persecution against Christianity, his life would willingly have been given up by him for her cause.

1778. We now turn our attention to a paper published by Lavoisier. The phlogistic theory had been necessitated to resort to a variety of subterfuges in order to maintain its ground: it was reserved for Lavoisier to destroy it completely. In 1778, he published a paper, which, by the arguments it contained, gave a death-blow to the hypothesis of Stahl. He proved that when sulphur is burned, sulphuric acid is formed; when charcoal, carbonic acid; and phosphorus, phosphoric acid. He also proved, that when substances burn in common air, a portion of the oxygen always disappears; and from this he deduced, that oxygen was necessary for the support of combustion. This is the fundamental principle of the anti-phlogistic, or Lavoisierian theory.

1780. In the Mem. de l'Academie for 1780, we have the results of a set of experiments made by Lavoisier and Laplace, with a newly invented instrument called the "calorimeter," the results of which, how remarkable soever, are not to be fully depended upon.

1784. The paper of Mr. Cavendish for this year,

(1784), published in the Transactions of the Royal Society, is entitled, "Experiments on Air," the principal fact in this paper being, the synthetical proof of the composition of water. Mr. Cavendish demonstrated the fact, that when hydrogen was burned in contact with atmospheric air, or oxygen gas, it combined with that gas, and formed water. The analysis of water was afterwards effected by Lavoisier. The discovery of the composition of water was seized upon by Lavoisier, as a grand proof of the anti-phlogistic hypothesis. Until this fact was ascertained, the opinions of Lavoisier were not all admitted previous to this time. A. D. 1784.

About the present period of chemical improvement, four contemporary chemists existed, whose first attempt was to contrive a chemical nomenclature. The old chemists had given names so preposterous and absurd to many of the substances known to them, that it was difficult to know what was meant by the terms of their unwieldy vocabulary. MM. Berthollet, Fourcroy, Guyton de Morveau, and Lavoisier, united for the purpose of effecting so desirable a change. But as this nomenclature was found more favourable to the hypothetical views of Lavoisier, than concordant with demonstrated facts, it has fallen into disuse; chemists now naming the several 1785.

A. D. 1785. substances under their cognizance according to their composition.

M. Fourcroy was the first who published a system of chemistry. He has been accused, but it appears very unjustly, of acceding to, or at least of not attempting to prevent, the murder of Lavoisier by the blood-thirsty democrats in the reign of terror. But this, upon mature deliberation, appears to be an invention of his enemies to tarnish the character of this celebrated man. Whether he could have prevented the death of Lavoisier, even with the risk of his own life, is a very doubtful question.

To pass from a subject so disagreeable, and at the same time so mysterious, we now come to the consideration of the favourite of Napoleon, Berthollet.

The character of Berthollet, as a chemist, stands very high. His acute perception predicted the downfal of the anti-phlogistic theory, long before that event came to pass. He asserted, as early as the year 1785, that oxygen was not the sole acidifying principle, inasmuch as sulphuretted hydrogen was an acid in all its properties, and yet contained no oxygen.

By the zeal, ardour, and activity of Berthollet, in communication of the facts relative to the making of musquetry, France was indebted for preventing an invasion from foreign

troops. We cannot help looking with pleasure upon the character of a man, who, to the highest attainments in science, adds a firmness and consistency of moral conduct. An anecdote related by Dr. Thomson, will serve to illustrate this observation. The ruffian Robespierre, among other manœuvres, was in the habit of getting up pretended plots, in order that he might arrest and murder with some shadow of justice. In accordance with this plan, he discovered that a conspiracy had been set on foot to destroy the soldiers, by giving them poisoned brandy previous to an engagement. Berthollet was ordered to analyze the brandy. Every one was aware that opposition to Robespierre was certain death, and the anticipated result was, that Berthollet would either find or make the brandy poison. But what was the general astonishment, when he sent in a report to the Committee that the brandy was perfectly free from poison, but that it had been diluted with water holding small particles of slate in suspension. Robespierre, enraged at this detection of his stratagem, arraigned Berthollet before the Committee for Public Safety; and after the futile endeavour to convince him that his analysis was inaccurate, Robespierre exclaimed—"What, sir! darest thou affirm that the muddy brandy is free from poison?" Berthollet immediately filtered a glass, and drank A. D. 1785.

A.D. 1785. it in his presence. "Thou art daring, sir, to drink that liquor!" exclaimed the ferocious president. "I dared much more when I signed my name to that report," replied Berthollet. "There can be no doubt," adds the historian, "he would have paid the penalty of this undaunted honesty with his life, but that fortunately the Committee for Public Safety could not at that time dispense with his services."

Berthollet had for a pupil in chemistry, Napoleon, after his return from Italy. For Berthollet he always evinced the sincerest regard; and as a proof of this, when he was informed that Berthollet had impaired his resources by the cultivation of his favourite science, Napoleon gave to his companion one hundred thousand pounds. The melancholy death of his son, M. A. B. Berthollet, in whom his hopes were concentrated, was an event of which Berthollet himself never got the better.(*f*) This event, together with the downfal of Napoleon, and the restoration of the royal

(*f*) M. A. B. Berthollet put an end to his existence under the following circumstances. Being afflicted with great depression of spirits, he retired into a room alone, in which was a charcoal brazier; and locking the door, placed his writing materials on the table, together with a second watch. He lighted the charcoal, and continued writing until the fumes of the poison stupified him, and he fell dead upon the floor.

family, hastened his death, which took place in 1822, at the age of seventy-four. A. D. 1785.

There is much omitted in the close of this century which ought to have been recorded. The discovery of zirconium, uranium, and titanium, by Klaproth; of chromium and glucina, by Vauquelin; and a variety of matter which the limits of my Introduction (already so much enlarged) have necessarily prevented.

It now only remains for me to commence the nineteenth century—one which far exceeds the former in the variety of its discoveries, and in their utility as applied to the comforts of life. 1800.

The nineteenth century commences with a paper of Volta, describing the apparatus called after him the Voltaic(*g*) pile.* The names of Galvani and Volta will be held in remembrance as long as science is cherished, and great discoveries commemorated. An accident directed the mind of Newton to investigate the laws of gravitation; and an accidental discovery of the effects of copper and zinc upon the nerve of a frog's leg, presented to the world the most powerful agent with which it has ever been acquainted. The analytical agency of gal-

* Philosophical Transactions for 1800.

(*g*) The Voltaic pile is made of a series of alternate circular layers of zinc, copper, and wet card, commencing with a layer of zinc, and terminating with one of copper, the last card being omitted.

A.D. 1800. vanism was also accidentally discovered by Messrs. Nicholson and Carlisle: for while those gentlemen were experimenting, in order to ascertain the positive and negative pole of the Voltaic pile, they observed that when a drop of water, which happened to fall on the uppermost plate of the pile, was connected with the undermost plate by means of a gold wire attached to that plate, it was decomposed.

In this year also, the first work of Sir Humphrey Davy was published.* And in the following year that great philosopher presented to the Royal Society a paper, entitled, "An account of some galvanic combinations formed by the arrangement of single metallic plates and fluids, analogous to the galvanic apparatus of Volta." This paper contains the germ of that discovery which, in a few years after, burst forth upon the world. I have not space to enumerate the various results of the application of galvanism to chemistry, and I must therefore merely give the most prominent experiments.

1803. The only important analyses of this year were those of that celebrated chemist Berzelius, which were published in conjunction with Hisinger. From them we arrived at the composition of eleven different salts; and, in the course of the decomposition, Berzelius ascertained that the acid attached itself to the

* Chemical Researches.

positive wire, and the base of the salt to the A. D. 1803.
negative; consequently the necessity of using wires, (such as gold and silver)(*h*) not easily oxidizable, was demonstrated. To Sir Humphry Davy, however, we are indebted for the most interesting experiments with galvanism.

In 1807, Sir Humphry read the Bakerian 1807.
Lecture, in which he proved that potassa and soda were compound bodies, and that their bases were metallic.

The paper of Sir Humphry for the present 1810.
year, (1810), demonstrated the elementary nature of chlorine; and shortly after this discovery, his "Elements of Agricultural Chemistry" were published.

In 1815, the most useful discovery of Sir 1815.
Humphry Davy was presented to the world—I say, most useful, because by it the lives of an infinite number of our fellow-creatures were saved: until the safety-lamp was invented, the miner was exposed to the danger of being blown to atoms by an inflammable atmosphere, every time it was necessary for him to enter the mine. With the safety-lamp he can enter, without any apprehension, the most dangerous and deleterious atmosphere. As the safety-

(*h*) I have purposely omitted the researches of Mr. Dalton, published 1804, as I shall be obliged to dwell upon them in the latter part of this work.

A.D. 1815. lamp is a subject of considerable importance, I shall describe the mode of its formation.

Sir Humphry had ascertained, by a course of experiments, that wire gauze prevented the transmission of flame; and consequently, that a lamp surrounded by wire gauze (which was impermeable by flame) might be placed with safety in an explosive atmosphere. But considerable danger might yet be incurred: the lamp of the miner was liable to be extinguished by the noxious air, which was incapable of supporting combustion. This difficulty was obviated by surrounding the wick of the lamp with very fine platina wire; so that although the lamp was extinguished by the vapour in the coal mine, it was rekindled the moment it was placed in an atmosphere capable of supporting flame. This invention was one which, for its ingenuity and originality, claimed for Sir Humphry the well-merited appellation of the first chemist in Europe.

1820. I am sorry that the results of his experiments with regard to the copper sheathing of vessels, was not equally productive of fame for this great man. These, his later efforts, were opposed by a concatenation of circumstances which could not be expected or foreseen. The disappointment of this scheme, and some other ci rcumstances, ultimately occasioned the death of the most original genius

and the greatest philosopher the annals of England or Europe can boast.* A. D. 1820.

The works of Sir Humphry Davy are written in the most easy and correct style, and may well be considered as a model worthy of imitation. A list of them may be found in the life of Sir Humphry by Dr. Paris, at the close of the second volume.

I have refrained from making any comment upon the living chemists, whose discoveries have adorned the present day. Writers on any science stand like culprits before the bar of the public, accused of the common crime of publishing; and it would ill beseem any one to set himself up as a judge of his fellow-labourers. The philosophers of former times, whose works are "monumentum ære perennius," are the property of the world—their names are held in veneration by all; and it is therefore the privilege of every person writing the history of philosophy, to pass that sentence upon them which his judgment has formed. "*De mortuis nil nisi bonum*," is a motto which may well be adopted; for it seems scarcely possible that any man can insult the memory of these great men, without exposing himself to the application of the proverb, "a living ass kicking at a dead lion."

There is one name, however, which I have not been able chronologically to insert, 1700–1834.

* See Dr. Paris, vol. ii.

A. D. 1700—1834.

without which, the pages of any volume on chemistry would be wanting one of its most valuable ornaments—I mean Dr. Wollaston. It does not fall within the limits of my subject to descant upon the valuable improvements in philosophical apparatus contrived by this eminent man. His first paper was published in 1797; it was an analysis of some gouty concretions. In 1804, he made known to the world the two metals palladium and rhodium; and in 1809, he proved the metal tantalum to be identical with the previously discovered columbium of Mr. Hatchett. His great ingenuity in contrivances for chemical analysis have gradually been published to the world, although his uncommon modesty would never allow him to describe them in print. I cannot here refrain from mentioning one ingenious application of his chemical skill. His object was to obtain a wire, for some purpose connected with the microscope, so fine as not to interfere with the sight. In order to accomplish this, he enclosed a platina wire in the centre of a silver one; and, producing the silver one as far as its ductility would permit, the platina wire enclosed in the silver one was of course in the same proportion to that silver one as the centre of a circle would be to its circumference. The next step was to separate the one from the other. Having ascertained that silver was

soluble in nitric acid, and platina insoluble, he effected the separation of the wires by placing them in that liquid; and the result of the experiment was, a platina wire scarcely visible to the naked eye, being only $\frac{1}{30000}$ of an inch in diameter. About the same time that Dr. Wollaston discovered the metals palladium and rhodium, Mr. Smithson Tennant detected osmium and tridium; all four metals being detected in the ores of platina. A. D. 1700—1834.

In 1818, Professor Stromeyer, of Göttingen, recognized in some ores of zinc the metal cadmium; and, in a few years after, Berzelius ascertained silicium and zirconium to be metallic bodies. For some others, I must refer to the table at the end of the Introduction.

Having concluded the history of chemistry, it now only remains for me to take a brief survey of the science as it is now, and to trace the causes of its rapid progression.

The nomenclature of chemistry being very important, (the science claiming justly the appellation of a mathematical science,) of course must be derived from facts as free from subversion as possible; because, if the names of the various substances in the laboratory were dependent on hypothesis, their number would baffle the

A.D. 1700–1834. most powerful memory—and, more than this, they must be for ever liable to change; consequently it has appeared prudent to chemists to name every substance according to its composition, as ascertained by analysis.

Mr. Dalton's discovery of the definite proportions in which substances chemically unite, has materially facilitated the nomenclature; and the more recent discovery, that a body uniting with another in more proportions than one, obeys the law of multiples, has rendered the system almost perfect. This is best illustrated by an example.

Oxalate of potash is a compound of oxalic acid and potash; and from analysis we ascertain that 48 parts of potassa are united with 36 parts of oxalic acid;(*i*) and it is proved that these substances will not unite in any proportions but 48 and 36. But the oxalate of potash is not the only compound formed by oxalic acid and potassa: we have the binoxalate and the quadroxalate, which are thus composed:

Name.	Composition.	
	Base.	Acid.
Oxalate of potassa . . .	48 .	36.
Binoxalate of potassa . .	48 .	72 = 36 + 2.
Quadroxalate of potassa .	48 .	144 = 36 + 4.

(*i*) I have not taken the correct equivalents for these substances, but the nearest whole numbers; and, for the sake of illustration, I have omitted the water of crystallization in the salts.

A. D. 1700—1834.

From this we perceive that the acid unites in multiple proportions, the number 36 being contained twice in 72, and four times in 144. Immediately this was perceived, the form of expressing the composition of the various substances was rendered shorter by substituting the word 'equivalent,' or 'combining proportion,' considering the whole 48 parts of potassa as one equivalent or combining proportion of potassa. Thus the composition of the oxalates of potassa would be thus expressed :

The oxalate is composed of	1 eq. of acid, and		1 eq. of base.	
The binoxalate . .	2	ditto	1	ditto.
The quadroxalate .	4	ditto	1	ditto.

And hence arose the terms, bin-oxalate, quadroxalate, &c. from *bis* and *quatuor*. For the sake of precision, when speaking of gaseous combinations, the Greek derivation is resorted to; for example, the compounds of nitrogen and oxygen.

Prot-oxide*	1 proportion of oxygen, and		1 pr. of nitrogen.	
Deut-oxide,	2 .	ditto .	1	ditto.
Trit-oxide,	3 .	ditto .	1	ditto.
Tetr-oxide,	4 .	ditto .	1	ditto.
Pent-oxide,	5 .	ditto .	1	ditto.

* Derived from πρῶτος, δεύτερος, τρίτος, &c. the Greek numerals.

The above is merely a specimen of what the nomenclature ought to be if strictly followed. Chemists retain, for the three last of these compounds, other names indicating their acid

A. D. 1700—1834.

properties, inasmuch as it facilitates the nomenclature when these acids unite with bases to form salts. Thus we may find that two general rules are followed in naming substances:—Whenever a substance has acid properties, it loses its compositional name, and takes another from the base of which it is the acid. The second rule is, whenever a substance is at its highest state of oxidation, it is called a peroxide. For example: potassium, the metallic base of potassa, unites with oxygen in two proportions; forming, first, the protoxide; and secondly, the peroxide, which is properly a tritoxide, no deutoxide being known.

The English chemists mark the distinction between the acids by the terminations "*ous*" and "*ic*," the former denoting a minor proportion of oxygen in its composition than the latter, as nitrous acid, nitric acid.

But notwithstanding this great improvement, Berzelius has effected a much greater, by the institution of a set of chemical symbols, which have the property of making the composition of each substance by dots and marks over the initial letters. The want of these symbols has long been felt as a great desideratum in chemistry. Berzelius, in the selection of the names from which the symbols have been formed, adheres to the Latin language, inasmuch as that language is known to all civilized nations.

The following table will exhibit the symbols of the elementary bodies: it is extracted from Dr. Turner's Elements of Chemistry, p. 35. A.D. 1700—1834.

Elements.	Symb.	Elements.	Symb.
Aluminium	Al	Mercury (Hydrargyrum)	Hg
Antimony (stibium) .	Sb	Molybdenum	Mo
Arsenic	As	Nickel	Ni
Barium	Ba	Nitrogen	N
Bismuth	Bi	Osmium	Os
Boron	B	Oxygen	O
Bromine	Br	Palladium	Pd
Cadmium	Cd	Phosphorus	P
Calcium	Ca	Platinum	Pl
Carbon	C	Potassium (Kalium) .	K
Cerium	Ce	Rhodium	R
Chlorine	Cl	Selenium	Se
Chromium	Cr	Silicium	Si
Cobalt	Co	Silver (Argentum) . .	Ag
Columbium (Tantalum)	Ta	Sodium (Natrium) . .	Na
Copper (Cuprum) . .	Cu	Strontium	Sr
Fluorine	F	Sulphur	S
Glucinium	G	Tellurium	Te
Gold (Aurum) . . .	Au	Thorium	Th
Hydrogen	H	Tin (Stannum) . . .	Sn
Iodine	I	Titanium	Ti
Iridium	Ir	Tungsten (Wolfram) .	W
Iron (Ferrum) . . .	Fe	Vanadium	V
Lead (Plumbum) . .	Pb	Uranium	U
Lithium	L	Yttrium	Y
Magnesium	Mg	Zinc	Zn
Manganese	Mn	Zirconium	Zr

These are the symbols of the elementary substances; consequently the combinations of many of these would be thus expressed:

Ca + O, or calcium and oxygen would be lime.

Ka + O, or potassium and oxygen would be potassa.

Fe + O, or iron, (ferrum) and oxygen would be oxide of iron.

In the case of deutoxides it would be—

N + 2O for deutoxide of nitrogen.

A. D. 1700—1834.

But as this has been considered rather unwieldy, Berzelius has instituted dots over the symbol to signify the state of oxidation of the substance. Thus, carbonic acid, a compound of two equivalents of oxygen and one of carbon, is symbolized by putting C, the symbol of carbon, with two dots over it, as $\ddot{C}$; the compounds of sulphur by commas, as $\acute{H}$, or hydrogen + sulphur, for sulphuretted hydrogen, or, as it is more properly designated, hydrosulphuric acid.

Another form of Berzelius is to indicate two equivalents by a dash under or through its symbol, as $\not{H}$ or $\underline{H}$ for 2H, and so on; and he makes use of the algebraic vinculum to designate the bisalts and others in the following manner:

$$(K + O) + (S + 3O) \text{ is sulphate of potassa.}$$
$$(K + O) + 2\,(S + 3O) \text{ is bisulphate.}$$

The above may be expressed by the dotted system; but I have here given the full formula, in order that it may be clearly understood.

Lastly, he uses the algebraic indices to denote two or more equivalents of one constituent of a compound substance: thus, ammonia is composed of three equivalents of hydrogen, and one of nitrogen; therefore the common Berzelian formula would be—

$$N + 3H.$$

This, however, is modified into NH^3.

The vegetable and animal acids are expressed by a dash over the initial letter, as $\overline{T}$ for tartaric acid, and so on.(*k*) It is to be hoped that these most elegant and easily applied symbols will soon come into general use: the advocacy of Dr. Turner is a sufficient guarantee for their usefulness, and assures us that they will become general. A. D. 1700—1834.

This introduction to the nomenclature will be sufficient upon the present occasion. We now turn to chemistry as it is:—this may be seen by comparing it with any of the collateral sciences, geology or mineralogy. The geologist takes an extended view of nature; he no sooner beholds the vast range of the Alps mountains, but he instantly associates it with the Mediterranean sea: he says, "This vast range of mountains, at some former period of the world, was most probably in the chasm which is now occupied by the waters of the Mediterranean, but which have been, by some vast volcanic eruption, cast forth upon the site they now occupy." This is of course purely hypothetical—not so with chemistry. A fact to be chemically established, or a theory to be received by a chemist, must have a demonstration as purely mathematical as possible: no theory

(*k*) These remarks are chiefly extracted from Dr. Turner's Elements of Chemistry, (pp. 235—238), fifth edition.

A. D. 1700. can have place in the nomenclature until established by well ascertained facts.

Chemistry being, then, a science thus constituted, what it teaches us has the warranty of demonstration, dependent, however, upon the powers of analysis which the present state of the science affords. In accordance with this, we have upwards of fifty substances which we call elementary, because we cannot reduce them to a more simple state. It is useless for me to proceed with the state of chemistry; it would swell this Introduction, and after all be very incomplete. I shall therefore now take a brief review of the progress of chemistry in the last century, and enquire to what causes its rapidity is to be attributed.

1700—1714. During the reign of Queen Anne, who, in the words of Smollett, "if not the greatest, was certainly one of the best and most unblemished sovereigns that ever sat upon the throne of England," science continues progressively improving, although the long-continued wars prevented the government from giving any pecuniary encouragement to science, had they been prompted so to do. The names of Swift, Pope, and Steele, adorn this era; but I cannot find any man particularly eminent in the science of chemistry.

In the reign of George the First, we have the satisfaction of beholding three names

which call for our respect—Dr. Halls, a chemist of our country, and Geoffroy and Reaumur, continental philosophers: the last name is distinguished for his improvement in the scale of the thermometer, although the centigrade is now almost universally adopted. There are no contemporary sovereigns, at this time, any more zealous for science than our own monarch appeared to be; but this is certainly more the fault of his venal ministry than his own, for never was the character of an individual so altered as that of the Elector of Brunswick when he became George the First of England. A.D. 1714—1727.

In the reign of George the Second, learning made rapid advances. Several translations of the classics were commenced with spirit; music flourished in Handel; but amidst this general stir, this thirst for knowledge, philosophy retrograded, and the Royal Society is thus spoken of by Smollett: "As for the Royal Society, it seems to have degenerated in its researches, and to have had very little share, for half a century at least, in extending the influence of true philosophy."* The great misfortune was, that no improvement was countenanced by the throne; every thing for the advancement of science was done by private individuals. The only continental philosopher was Leibnitz, a name certainly which is equivalent to a host in itself. 1721—1760.

* Vol. xvi. p. 382.

A. D. 1760—1820. Upon the accession of George the Third, the cabinet was too much occupied in providing for the urgency of the times, to attend to knowledge under any shape. The threats of the last branch of the house of Stuart alarmed the ministry, and the money spent in secret service money, and other expenses equally necessary, put a stop to all the hopes of philosophers for support from the throne; all that could be saved was appropriated to the men of talent who wrote for the ministry of the day. In the continuation of the reign of this virtuous monarch, many philosophers of considerable eminence (whom I have already mentioned) made their appearance, but the name of Watt is the greatest ornament to the reign. Mr. Watt, as the improver of the steam-engine, is unequalled; the great saving of steam, and the resulting increase of power, in Mr. Watt's engine, is immense. Sir Walter Scott has thus delineated the character of Watt: "He was a man whose genius discovered the means of multiplying our national resources to a degree, perhaps, even beyond his own stupendous powers of calculation and combination; bringing the treasures of the abyss to the surface of the earth; giving the feeble arm of man the momentum of an Afrite; commanding the manufactures to arise, as the rod of the prophet produced water in the

desert; affording the means of dispensing with that time and tide which wait for no man, and of sailing without that wind which defied the commands and threats of Xerxes himself. The potent commander of the elements, the abridger of time and space, this magician, whose cloudy machinery has produced a change on the world, the effects of which, extraordinary as they are, are perhaps only now beginning to be felt, was not only the most profound man of science, the most successful combiner of powers and calculator of numbers, as adapted to practical purposes; was not only one of the most generally well informed, but one of the best and kindest of human beings. In his eighty-fourth year, his attention was at every one's question, his information at every one's command." The Lord Advocate of Scotland thus speaks of Mr. Watt and his improvements:* "This name, fortunately, needs no commemoration of ours; for he that bore it, survived to see it crowned with undisputed honour; and many generations will probably pass away, before it shall have gathered all its fame. We have said that Mr. Watt was the great improver of the steam-engine; but in truth, as to all that is admirable in its structure, or vast in its utility, he should rather be described as its inventor.

* * * *

A. D. 1760—1820.

* In a speech just after Mr. Watt's death.

A.D. 1760—1820.

The trunk of an elephant, that can pick up a pin or rend an oak, is nothing to it. It can engrave a seal, or rend masses of the most obdurate metal; draw out, without breaking, a thread as fine as gossamer; lift up a ship of war like a bauble in the air; it can embroider muslin, cut steel into ribands, and impel loaded vessels against the fury of the wind and waves." Such is the character of Watt as drawn by Sir W. Scott and Mr. Jeffreys.

There is a name, however, to whom, as a promoter of science, all respect is due—the Emperor Napoleon Bonaparte. I am not about to panegyrize this great man, but merely to advance a fact, which, now that all political animosity has subsided, may be stated, and the meed of honour acceded to whom it is due. As a general, skilful though he was, he was excelled by the Duke of Wellington: as the First Consul, the laurels which he had previously acquired were tarnished by the blood of D'Enghien. As the Emperor of France, his very coronation was attended by an insult to his Holiness the Roman pontiff; and as the imperial exile on his isolated rock, the mind of the man who once swayed the destinies of Europe, condescended to the meanness of libelling Sir Hudson Lowe. But, as a promoter of science, no monarch ever equalled him in liberality, no monarch ever came up to him in munificence

to the cultivators of philosophy. This was the only point in his character which was perfect. His present to Berthollet of one hundred thousand crowns is an example of this, which will always exist as a memorial of the bounty of the Emperor Napoleon Bonaparte. What a lesson! The man whose time was engaged more than any of his cotemporaries, found time to patronize, and even to study the science of chemistry. No monarch of our own country (if we except his late Majesty King George the Fourth) ever patronized learning or literary men. The time will come when the voice of the rabble will not be heard in tumultuous discord against the monarch whose private faults were few, but his public virtues many. Posterity will decide, when the name of George the Fourth will descend to them embalmed in the history of science, and his nameless slanderers are gone to answer for their libels against a monarch, whose throne was the seat of mercy, whose heart was filled with benevolence, charity, and patriotism. In the words of a poet,

A. D. 1760—1820.

"Oh! if defects the best and wisest have,
Leave them in mercy, leave them to that God,
Who lifts alike the balance and the rod,
And close with parting prayer the curtain o'er the grave."*

* Bowles.

Such is a brief and imperfect attempt to delineate the progress of chemistry.

A.D. 1760—1820.

May science continue to flourish as long as it shall be conducive to the collateral verification of religion and the happiness of man. In the present age of boasted intellectual advancement, it is remarkable that nothing has been done by the directors of the *march of intellect* for the support of scientific men, although they pretend to so high a veneration for science. While vast sums are expended upon Utopian schemes, such as the civilization of the savages of Hindostan, and the Ourang-outangs of the desert,(*l*) the men who spend the prime of life in the cultivation of science, are left to the protection of chance for their sustenance in old age.

(*l*) Notwithstanding all the mischief these well-intentioned individuals do themselves and the community, still the visionary delusion is carried on; the unfortunate philanthropist finds, for the most part, the wild beasts and the savages a sort of Scylla and Charybdis; if he escape the one, most probably he will perish by the other. While so much remains to be done in our own country, while Ireland is in a state of so much distress, while the poor are perpetually at our door, oh! why indulge in schemes of fancied benevolence, and turn a deaf ear to the cry of thousands who are united to us by the tie of fellow-countrymen.

CHEMICAL ATTRACTION.

CHAPTER I.

LAWS OF COMBINATION.

Attraction defined.

ATTRACTION may be defined as a force or power existing between two bodies, which imparts to both of them a tendency to approximate one another. Philosophers have considered the laws of attraction under three distinct classes :—

1. The attraction of cohesion.
2. The attraction of gravitation.
3. Heterogeneous, or chemical attraction.

Attraction of cohesion.

The first exerts its influence upon a single substance by which the particles of a body are united and adhere one to another. The attraction of cohesion is sometimes called the attraction of aggregation, or attraction "en masse," when two substances of similar natures are brought together: for example, when two leaden bullets are scraped with a knife, and the two parts thus scraped are brought into

contact with a gentle pressure, they cohere, and require the application of some force to effect a separation between them. The attraction of aggregation is also exerted between any two masses, however dissimilar in nature. For instance, in taking the altitude of a mountain, or any problem of perpendicular altitude, great care must be taken to allow for this force; for if a plummet be let down by the side of a large mass, the plummet will not fall in a straight line, but will be attracted considerably towards the mountain.

Attraction of gravitation.

The attraction of gravitation is the law discovered by Newton, by which all bodies are attracted to the centre of the earth, and by which the planets are kept in their respective orbits. I have not space to enter into each of these, but must confine myself to the object of this Essay, "Chemical Attraction."

Chemical attraction.

Chemical attraction is a power existing in two separate substances dissimilar in nature, but which, when brought together (under certain circumstances), unite and form a third substance, differing in nature from its two constituents. The great distinction between chemical attraction and the two former laws is, that whenever two substances are united by the agency of chemical attraction, a change of form is the inevitable consequence. Sometimes this change of form is accompanied by

change of colour, sometimes by change of property, (the resulting compound differing in property from its constituents,) and not unfrequently it is attended by an evolution of light and heat sufficient to cause combustion. These statements are illustrated by experiment:—

1. Change of form results when sulphuric acid and muriate of lime are brought together; the two liquids are converted into a white permanent solid, namely, sulphate of lime. The same result is observed when any soluble salt of baryta is brought in contact with sulphuric acid.

Change of form attending chemical attraction.

2. Change of property. The common salt which is used for culinary purposes, is a very striking illustration of this. The constituents of salt are chlorine, a gas highly deleterious to life, and sodium, a metallic base certainly dangerous as a metal (or even as its oxide) if admitted into the stomach; yet these two substances combining form common salt, a most wholesome adjunct to almost every article of food.

Change of property accompanying chemical attraction.

3. Change of colour is too remarkable an incident to need any notice, the toxicological evidence of chemists being derived from it in many cases. The doctrine of tests depending materially upon it, I shall only adduce two or three instances. When hydriodate of potash

Change of colour accompanying chemical attraction.

is brought into contact with any salt of lead in solution, the yellow iodide of lead is formed. Again, when the ferroaganate of potassa is brought into contact with any solution of iron, the beautiful pigment Prussian blue results. Solutions of copper with ammonia produce a deep blue: solutions of arsenic let fall a green precipitate when the ammoniated sulphate of copper is poured into them. The change of colour is also exemplified in the deutoxide of nitrogen gas, which, although colourless itself, immediately upon coming in contact with atmospheric air, is converted into a dark red orange-coloured compound, nitrous acid.

Chemical attraction attended with combustion.

4. Lastly, chemical attraction is sometimes accompanied with evolution of light and heat, sufficient to create combustion. When sulphur is heated with copper filings, a spark is seen to pass across the mixture, and it is immediately ignited. When moistened iodine and phosphorus are brought together, they burst into flame. And numerous other instances might be adduced; but these are enough to satisfy us that the statement is correct. The chemist is naturally directed to enquire into these changes; and this was attempted to be demonstrated by Bergman. This acute experimenter perceived that in bringing three substances into mutual play, two being united, and the other free, the attraction between the two former would be

overcome; the latter body would unite with one of the former.

Thus, let A represent sulphuric acid, and let B represent baryta, and C muriatic acid. Now B and C united form muriate of baryta, a soluble salt: upon adding A to the solution, B, which was formerly united to C, is displaced by A, and the result of the operation would be, A united to B, and C liberated. Consequently Bergman argued that there was a stronger attraction between A and B, than between C and B; and in pursuance of this, he drew up certain tables(*m*) indicating this attraction, and divided chemical attraction into two parts: the one simple *elective** attraction, the other complex elective attraction.

* Called elective, because it appeared to choose one body in preference to another.

Simple elective attraction is exerted when three agents are present, two combined and one free, as in the case of sulphuric acid and muriate of lime. The muriatic acid is liberated, and the sulphuric acid unites with the lime, forming sulphate of lime.

(*m*) The use of these tables was to exhibit the power of attraction in one substance dispossessing another. Thus, sulphuric acid has a stronger attraction for baryta, than it has for strontia; for strontia than for potassa; for potassa than for soda, and so on. The table according to Bergman therefore was—

Sulphuric Acid.

Baryta.
Strontia.
Potassa, &c.

Complex elective attraction is so called, because, in place of one combined agent and one free, we have two combined agents. Thus, sulphate of soda (composed of sulphuric and soda,) and muriate of baryta (composed of muriatic acid and baryta,) upon being mixed in solution, the acids exchange bases, and we have a sulphate of baryta and muriate of soda.(*n*)

The fallacy of depending upon the table drawn for the purpose of indicating any general result from experiments of this nature, was first shown by M. Dulong. That chemist detected the following discrepancy.

Upon boiling $\ddot{C} + \dot{Ba}$ in a solution of $\dddot{S} + \dot{K}$, we have resulting, $\ddot{C} + \dot{K}$, and $\dddot{S} + \dot{Ba}$. Upon reversing the experiment, and boiling $\dddot{S} + \dot{Ba}$, in a solution of $\ddot{C} + \dot{K}$, we have resulting $\dddot{S} + \dot{K}$, and $\ddot{C} + \dot{Ba}$.

From this experiment, and some others, M. Dulong came to the conclusions, " First, that all insoluble salts are decomposed by the carbonates of potassa or soda ; but that a mutual exchange of principles of these salts is never

(*n*) To illustrate all cases of chemical change, the Berzelian symbols are of very great utility. For example, in the case of simple elective attraction, $\dddot{S}$ mixed with HCl + $\dot{Ca}$, produces $\dddot{S}$ + Ca, liberating HCl. Complex attraction, $\dddot{S}$ + $\dot{Na}$ mixed with HCl + $\dot{Ba}$, produces $\dddot{S}$ + $\dot{Ba}$ and HCl + $\dot{Na}$.

complete. Secondly, that all the soluble salts of which the acid forms with the base of the insoluble carbonate an insoluble salt, are decomposed by these carbonates until the decomposition has reached a certain limit which it cannot pass."

Affinity.

The term *affinity* has been substituted by chemists for *attraction*, and certainly it is in many respects preferable; for the word attraction conveys an idea that the two agents are drawn into closer contact; whereas this is very often not the case: when copper and gold are alloyed, the resulting compound is much more bulky than before combination. Hydrogen and chlorine unite to form muriatic acid, without any condensation.

We have now seen that bodies unite chemically, and form resulting compounds, differing materially in form and property from either of their constituents: we shall now examine the laws by which bodies unite chemically, which have been denominated the Laws of Combination.

Bodies combine in three different methods:

1. They are simply mixed.
2. They are dissolved.
3. They are chemically united.

The first class comprehends all those substances which mix in indefinite proportions, such as sulphuric acid and water. One drop of sulphuric acid may be diffused over a gallon

of water, and give the most decisive proof of its presence in any portion of the water that is examined. Again, water and alcohol unite to any extent with one another; and so on with a variety of other liquids.

The second class affords a connecting link between the first and third; for in the first, the agents combine indefinitely; in the third, definitely; and in the second, definitely only to a certain extent. In dissolving any salt in water, after some time we perceive the water will refuse to dissolve any more of the salt, in fact it will become a saturated solution: and although, previous to the point of saturation, the union between the salt and the water is indefinite, yet, upon arrival at the point of saturation, it is definite; thus, if the solution, by the mechanical agency of heat, be made to pass the point of saturation, as the mixture returns to the ordinary temperature of the atmosphere, the excess is deposited either in the form of crystals or precipitate. It is by making use of this law that the finest crystals are obtained; for as the water can only contain a certain quantity of the salt, the more slowly any portion of that water is abstracted from the salt, the more beautiful will be the formation of the crystals; so that by allowing the water to evaporate spontaneously, we obtain a fine large crystal; whereas, if we

evaporate by the agency of heat, we have a small irregular crystal.

The last class of bodies falling under the laws of combination, are those which are chemically (that is definitely) combined. So that we perceive a beautiful connexion between these three classes. We have no direct hiatus between them; but, similarly to all the laws of nature, the links of division between different classes of the same family are so fine, that we hardly perceive a separation.

The first class is indefinite.

The second, indefinite to a certain point—then definite.

The third, definite altogether.

It is to the third class that we have more particularly to confine our attention.

It is found that if two substances are united, either by nature or by art, the proportions in which they unite are invariably the same. This law extends to the mountainous masses on the earth's surface, as well as to the salts now formed in the laboratory of the chemist.

The carbonate of lime which has existed for ages, is precisely the same in composition and in characteristic properties, as the small precipitate of the same substance, formed by the philosopher every day. Having ascertained the permanence of this law, in order to facilitate the study of chemistry, the facts

arising from a variety of experiments have been reduced to a scale of numbers expressing the relative proportions in which substances combine. For example,

8 parts of oxygen unite with		1 of hydrogen.
8 ditto	. . .	16 of sulphur.
8 ditto	. . .	39.15 of potassium.

And it has been confirmed by experiment, that oxygen always unites in the proportion of 8. The number of oxygen in the scale would be 8, hydrogen 1, sulphur 16, and so on. This scale certainly is most convenient, because it expresses in whole numbers a great many of the substances in chemistry. Oxygen is regarded as unity by some chemists, and Berzelius, with a view to obtain very great accuracy, has made oxygen 100 in his table. But the scales are easily reduced one to another by a simple process.

To find the value of hydrogen according to the scale of oxygen = 1, we have only to divide by 8, which gives 0.125.

When we apply these laws to any case of chemical change, we at once perceive its immense importance. For example: in mixing two neutral salts (in solution,) we see that there is no alkali in excess, nor any acid, because the acids can only combine in one

proportion, which proportion exactly agrees with the corresponding base: for example, in mixing sulphate of soda and nitrate of lime; sulphate of soda is composed of sulphuric acid and soda; and nitrate of lime, of nitric acid and lime. We have then,

Sulphate of soda.		Nitrate of lime.	
Sulphuric acid .	40	Nitric acid .	54
Soda	32	Lime . . .	28
Sulphate of soda .	72	Nitrate of lime	82

When the solutions are mixed, the 40 parts of sulphuric acid unite with 28 of lime, and form 68 of sulphate of lime; the 54 of nitric acid unite with 32 of soda, and form 86 of nitrate of soda. The neutrality of the solution is not all affected, in case the substances are not so exactly mingled; for if more than 72 parts of sulphate of soda be employed, then the overplus remains in solution undecomposed; and if the excess be on the other side, then nitrate of lime will remain undecomposed. We can now readily understand how these substances can combine and form neutral mixtures; indeed, we see it is impossible for it to be otherwise.

This leads us to notice the law of Dr. Dalton, by which he demonstrated that bodies unite with one another in multiple proportions. And here I would make a remark, that this

discovery is perfectly distinct from the theory of Dr. Dalton, which came out in conjunction with it. It has been too much the custom to mix up the two together, and to consider them under one name; whereas, this discovery is perfectly distinct from the atomic theory; the one being a statement of a most interesting fact, and the other a theory deriving considerable support from that fact, but still not at all necessary for the existence or proof of the fact itself. I wish to be understood as drawing this distinction, (which is marked very clearly,) and therefore we shall consider them as they are, totally distinct the one from the other. Dr. Dalton observed, that when one body united with another to form more compounds than one, the proportions advanced in arithmetical progression, as 1, 2, 3, 4, 5, &c. Thus, in the following table this is exemplified:

	Composition.
Protoxide of platinum .	platinum 98.8 + oxygen 8 or 1 eq.
Deutoxide of platinum .	platinum 98.8 + oxygen 16 or 2 eq.
Carbonic oxide . . .	carbon . 6 . + oxygen 8 or 1 eq.
Carbonic acid . . .	carbon . 6 . + oxygen 16 or 2 eq.
Nitrous oxide . . .	nitrogen 14 . + oxygen 8 or 1 eq.
Nitric oxide	nitrogen 14 . + oxygen 16 or 2 eq.
Hyponitrous acid . .	nitrogen 14 . + oxygen 24 or 3 eq.
Nitrous acid	nitrogen 14 . + oxygen 32 or 4 eq.
Nitric acid	nitrogen 14 . + oxygen 40 or 5 eq.

This is Dr. Dalton's discovery alone, and it

is certainly one of the most important in chemistry.

A second series has been noticed;(*o*) it runs in the proportion of 1, 1½, 2, 2½, 3, &c. I shall here subjoin a few of the substances which exemplify this law:

	Manganese.	Oxygen.
Protoxide of manganese	28 +	8 or 1 eq.
Sesqui oxide . . .	28 +	12 or 1½ eq.
Deutoxide	28 +	16 or 2 eq.

This is quite sufficient to illustrate the existence of the fact: I shall advert to it in the sequel, when considering the atomic theory.

In order to account for this great uniformity in all chemical compounds, Berthollet originated the supposition, that the definite proportions in which bodies combine were not the consequence of any inherent property in either of the substances, but that the union took place in those proportions because the cohesive power of the particles between the two substances was greater than they would be if united in any other proportions. This opinion would, of course, if substantiated, convert all the certainty of chemistry into vague uncertainty, indeed it would overthrow chemistry as a science.

(*o*) I am not aware to whom the chemical world is indebted for this discovery.

Proust, however, demonstrated the opinion to be perfectly fallacious.

I cannot pass over another theory of the laws of combination, which has for its original Sir Humphry Davy. Sir Humphry regarded all substances during combination as in two electrical states—the one *plus,* and the other *minus:* he also endeavoured to show, that the more intensely these different states existed in two bodies, the stronger their affinity for each other. From these premises Sir H. Davy and M. Ampère concluded that *electrical energy* and *chemical affinity* were identical forces. The consideration of this theory, which has been called the "electro-chemical," I shall leave to the next chapter.

CHAPTER II.

THE ELECTRO-CHEMICAL THEORY.

There have been many theories started in the science of chemistry to account for the diversified phenomena exhibited in the practice of that most interesting branch of natural philosophy; but these have for the most part been proved inefficient, and fallen into disuse. The electro-chemical theory has been the favoured one which almost all philosophers have fostered with parental care. To the establishment of this theory, they look forward as the beginning of the golden age of chemistry; and although it is at present inadequate to account for some facts, and I may say (as we at present understand it) very discordant with others, yet scarcely a chemist of the

present age has written without endeavouring to lend his assistance to the support of the electro-chemical theory. The name of its great originator, Sir Humphry Davy, and the labours of those who have, at various times and under various modifications, contributed to its establishment, such as Berzelius, M. Ampère, &c. unite to make it a favourite among men of science.

By adopting the electro-chymical theory, we are enabled to account for many cases of chemical decomposition by the action of a third body, more satisfactorily than by the Newtonian hypothesis. The theory has derived considerable confirmation from the facts, that in almost all cases of very intense chemical action, the agents have been found to be in these plus and minus (positive and negative) states. For example: sulphur is negative with regard to copper; upon being gently heated, a flash of light is seen to pass through the mixture, and the whole bursts into a flame. Potassium and oxygen are in opposite states: if potassium be thrown into water (a compound of oxygen and hydrogen), the oxygen is taken from the water, and the liberated hydrogen is inflamed by reason of the two electric substances gaining their equilibrium.

Some substances regain their electric equi-

librium more slowly than others. The pyrophorus powders(*p*) burn slowly and without

(*p*) There are several of these remarkable substances which have the property of burning without flame, (but at a dull red heat) upon being exposed to the air. As some of my readers may have a desire to witness this remarkable fact, I will give two or three formulas for the preparation of pyrophorus powders. The oldest is Homberg's pyrophorus.

To prepare this, take equal parts of alum (in powder,) and brown sugar, place them upon a fire, stirring them with a glass rod until reduced to dryness. The mixture, when cold, is to be finely powdered, and placed in a common vial, surrounded by clay, about $\frac{1}{8}$ of an inch in thickness about the bottle. The coated vial is now to be placed in a crucible filled with sand, and the whole apparatus placed in the fire. In a few minutes, gas will be seen to issue from the mouth of the bottle, which is to be set on fire. When the gas ceases to escape, the crucible, &c. is to be removed from the fire, and a little piece of clay put into the mouth of the bottle to prevent the action of the air: when cold, the clay may be removed, and a cork substituted. The pyrophorus is completed the moment the gas ceases to escape, and great care must be taken immediately to close the operation.

Gay Lussac made use of lamp-black in place of sugar; and by collecting the products which passed off, he came to the conclusion, that the pyrophorus remaining was composed of sulphuret of potassium, intimately blended with a few proportions of sulphur. The most amusing and easily procured pyrophorus is that formed by tartrate of lead. To prepare this salt, 162 grains of acetate of lead (in solution) must be mixed with a solution of 67 of tartaric acid. The precipitate must be collected and carefully dried. The remaining part of the manipulation is precisely the same as that given for Homberg. They all possess the property of spontaneous combustion,

flame. The solar phosphori(*q*) follow even a slower process; they merely emit light, with scarcely any perceptible heat.

We perceive from these facts, that the electro-chemical theory holds out great advantages, if it could be established; but there are difficulties attending it, arising from facts perfectly irreconcileable with it, which, in the present state of chemical science, cannot be made satisfactorily to coincide. The electrical hypothesis has certainly the merit of accounting for the development of heat and light; but we must not be led away to adopt a theory as perfect, merely because it agrees with a few facts. Moreover, the theory itself is based on an assumption; the agents which have been considered as positive and negative, are by no means proved to be so by experiment. That oxygen, existing as free uncombined oxygen, is perfectly neutral as far as regards its electrical state, is amply proved by its refusing to indicate its electrical excite-

differing very mueh aeeording to the substanee in whieh they are plaeed. On metal, the pyrophorus burns sometimes not at all; if it does burn, the combustion is only partial and very slow; whereas, on substances not good conductors, as paper, silk, and so on, the combustion is rapid.

(*q*) The solar phosphori are a family of substanees which have the power of absorbing light from the sun, and emitting it in the dark.

ment before the electrometer. We have then no right to conclude that the particles of a body are in a different electrical state from the mass itself. To me it appears, that the only way of satisfactorily reconciling these discrepancies, would be by supposing the bodies about to unite to have a predisposition to be thrown by contact, or some peculiar inherent property in themselves, into opposite electrical states.

Sir Humphry Davy founded his theory upon the fact, that in all decompositions, by the agency of galvanism, the elements separated, the one being disengaged at the positive pole, and the other at the negative pole of the galvanic apparatus. Thus, in decomposing potassa, we have the following arrangement:

Oxygen at the positive pole.
Potassium at the negative.

In accordance with these facts, Berzelius has given a table of the elementary substances, electrically arranged into two classes:—

1. *Negative Electrics.*	2. *Positive Electrics.*
Oxygen.	Potassium.
Sulphur.	Sodium.
Nitrogen.	Lithium.
Chlorine.	Barium.
Iodine.	Strontium.
Fluorine.	Calcium.
Phosphorus.	Magnesium.

1. *Negative Electrics.*	2. *Positive Electrics.*
Selenium.	Glucinium.
Arsenic.	Yttrium.
Chromium.	Aluminium.
Molybdenum.	Zirconium.
Tungsten.	Manganese.
Boron.	Zinc.
Carbon.	Cadmium.
Antimony.	Iron.
Tellurium.	Nickel.
Columbium.	Cobalt.
Titanium.	Cerium.
Silicium.	Lead.
Osmium.	Tin.
Hydrogen.	Bismuth.
	Uranium.
	Copper.
	Silver.
	Mercury.
	Palladium.
	Platinum.
	Rhodium.
	Iridium.
	Gold.

In looking at this table, we are at once struck with a remarkable fact that seems to threaten to overthrow the electro-chemical theory. If chemical combination is brought about by the union of two bodies in opposite electrical states, how is it that two bodies in the same state unite? But there is a phenomenon connected with this fact, which may be noticed here, which seems to confirm the hypothesis.

1st. Whenever any of the substances in the electro-negative class unite with oxygen in the same class, they form an acid. To this rule hydrogen is the only exception :

Oxygen, combining with electro-negatives, forms acid compounds.

Oxygen and sulphur form an acid.
Oxygen and nitrogen form an acid.
Oxygen and chlorine form an acid, &c.

This law holds good, not only as far as regards the common acidifiable bases, but even metals obey the same law :

Oxygen and chromium form an acid.
Oxygen and molybdenum form an acid.
Oxygen and osmium form an acid, &c.

And here we see another curious fact: no other metals but those on the negative side, form acids by union with oxygen.

2nd. Whenever oxygen combines with the positive electrics, the result is an oxide or an alkali, but not an acid. Manganese is an exception.

Oxygen, combining with electro-positive bodies, forms an oxide or alkali.

Oxygen combines with	potassium,	forming an alkali.
Ditto . .	sodium . .	ditto.
Ditto . .	lithium . .	ditto.
Ditto . .	zinc . .	oxide.
Ditto . .	copper . .	ditto.

Iron is the only metal found naturally magnetized, and iron is the only one which enters into any compound in a metallic state, which it is generally supposed to do in ferro-cyanic acid.

If we take any other element in the same class, we have nearly the same results:

Chlorine unites with	chromium, and forms	an acid.
Ditto . .	carbon . .	ditto.
Ditto . .	iodine . .	ditto.

Chlorine unites with	chromium, and forms	an acid.
Ditto . .	potassium . .	a chloride.
Ditto . .	sodium . .	ditto.

With iodine and the other negative electrics, when they unite, they form acid compounds; when they unite with positive electrics, they form oxides or chlorides. (*r*) Thus we perceive, that when two of the electro-negatives are united, they together unite with an electro-positive element, as muriatic acid.

Hydrogen and chlorine combine and form muriatic acid.
Sodium and oxygen combine and form soda.

Now the muriatic acid will unite with the soda, but not with the sodium. The chlorine will unite with sodium, as negative and positive electrics. Chlorine, however, will not combine when the negative element oxygen is a constituent; it will not combine with oxide of sodium, (*i. e.* permanently,) but it will combine with sodium by itself.

M. Ampère suggested a very ingenious

(*r*) Oxygen uniting with positive bodies forms an oxide, chlorine a chloride, iodine an iodide, and so on according to the name of the element.

modification of the theory. That philosopher considers every atom of matter to be essentially and unchangeably in a state either of positive or negative electricity. "The consequence of this," says Ampère, "will be, that the ultimate particles which are positive, will be surrounded with an atmosphere of negative electricity, and *vice versa* the ultimate particles which are negative, will be surrounded by an atmosphere of positive electricity. In the composition of water, the atoms, or ultimate particles of the hydrogen, previous to combination, are positive; consequently, the atmosphere surrounding them will be negative; and the atoms of oxygen are negative, consequently, the atmosphere surrounding them will be positive; when these gases unite, the first change is the neutralization of the electric atmospheres. The combination of the two electricities, in order to accomplish this neutralization, produces light and heat.

Thus we may account for the great development of heat and light so frequently accompanying chemical action. Beautiful as is this theory thus modified, it cannot be admitted: Dr. Thomson has given us sufficient evidence to overthrow it completely. That the heat and light are not the consequence of the electric neutralization, we have *prima facie* evidence; for the spark is always less bright

where the two electricities combine, (when taken from a conductor) than at any other part. Again: the very assumption that particles of matter are "essentially and permanently in the same electrical states," requires to be proved. For instance, sulphur and oxygen unite and form an acid; when this acid is decomposed by the galvanic agency, the oxygen attaches itself to the positive pole, and the sulphur to the negative: hence we conclude that sulphur is positive, and oxygen negative. Again: sulphur and hydrogen unite and form an acid; when this acid is similarly decomposed, the hydrogen is found to be positive, and the sulphur negative: consequently, hydrogen (that is, each ultimate particle of hydrogen) is both positive and negative, which is impossible.

Dr. Thomson considers that both positive and negative electricities are present in all bodies—an opinion certainly more in accordance with established facts than the former. We are not certain whether electricity be a material or an immaterial agent, but we have some tolerable evidence for declaring it to be material. Let us then suppose it material, and subject to the laws of material bodies. We know from experiment, that the atoms of different bodies differ very materially in size; consequently, when two atoms differ-

ing in size approximate, the law of attraction "en masse" is brought into play; the positive electricity of the larger atom being excited, and the negative of the smaller, they therefore combine, and an equilibrium is effected. Thus we perceive that substances whose atoms are nearly the same in size, form compounds easily separated by other agents.

There is one fact, however, which is totally incompatible with the electro-chemical hypothesis. If the vapour of water be passed over red-hot iron, the water is resolved into its elements; hydrogen is disengaged, and oxide of iron formed. On the contrary, if oxide of iron be heated to redness in contact with hydrogen gas, the very reverse of the former experiment is the result; the hydrogen combines with the oxygen of the oxide, and forms water, and the iron is left in the metallic state. "These two decompositions," says Dr. Thomson,* "appear to be incompatible with each other. Hydrogen is undoubtedly much more positive than iron; it ought, therefore, to be able to deprive this last metal of oxygen. The reduction of the oxide of iron by means of hydrogen, is what we should expect. When iron decomposes steam, its temperature is raised to redness, and undoubtedly the temperature of the steam is much lower. Shall we conclude from this, that heat is capable of

* System of Chemistry, Introd. vol. i. p. 47.

exalting the positive electricity of the iron, so much as to enable it to surpass that of the hydrogen at a lower temperature? This at least is the only explanation which occurs to me as at all approaching a satisfactory solution of the difficulty."

I shall conclude this chapter with the following tables, taken from Dr. Thomson's Introduction to the System of Chemistry, p. 48.

Table I. begins with the most positive non-metallic element, and ends with the most negative.

Hydrogen	Sulphur
Boron	Azote
Silicon	Iodine
Carbon	Bromine
Arsenic	Chlorine
Phosphorus	Fluorine?
Selenium	Oxygen.

"Hydrogen is positive with respect to every body. Oxygen is negative with respect to every body. Sulphur is positive with regard to all the substances below it; but negative with respect to all the substances above it. The same thing applies to all the bodies in the table, each is negative to every body above it, and positive to every body below it."

Tables II. and III. exhibit the bodies with which each of these substances is capable of combining, arranged according to their greatest electro-negative energy, and therefore in the order in which they decompose each other.

TABLE II.

1 Hydrogen.	2 Boron.	3 Silicon.	4 Carbon.	5 Arsenic.
Fluorine	Fluorine	Fluorine	Oxygen	Oxygen
Chlorine	Chlorine	Chlorine	Chlorine	Fluorine
Oxygen	Oxygen	Oxygen	Iodine	Chlorine
Bromine	Sulphur	Sulphur	Sulphur	Bromine
Iodine			Azote	Iodine
Sulphur				Selenium
Selenium				Sulphur
Carbon				Phosphorus
Phosphorus				
Arsenic				
Azote				

TABLE III.

6 Phosphorus.	7 Selenium.	8 Sulphur.	9 Azote.	10 Iodine.	11 Bromine.
Oxygen	Oxygen	Oxygen	Chlorine	Oxygen	Chlorine
Fluorine	Chlorine	Chlorine	Iodine	Chlorine	Oxygen
Chlorine	Bromine	Bromine	Oxygen	Bromine	
Bromine	Iodine	Iodine			
Iodine	Sulphur	Selenium			
Selenium					
Sulphur					

"The only substance more electro-negative than chlorine, is oxygen. And as we know no substance more electro-negative than oxygen, of course no column under oxygen can be drawn up."

CHAPTER III.

THE ATOMIC THEORY OF DR. DALTON.

The opinions of chemists have long been divided concerning the constitution of matter; some considering it as divisible *ad infinitum,* provided that our instruments were sufficiently fine, and our sight proportionally adequate; while others, on the contrary, maintain that when we arrive at a certain point, we are bound, philosophically speaking, to consider matter indivisible.* To decide between these conflicting testimonies is not the prerogative of the chemist, but it is for him to assume that theory which affords the most clear rationale for the various phenomena that fall under his cognizance.

* Among the ancient philosophers Epicurus maintained this opinion.

It seems probable at first sight, that the theory of the divisibility of matter *ad infinitum* is correct. We can imagine matter to be so finely divided, that the eye cannot follow, or

the instrument effect, any further division of its particles; whereas it is difficult for us to conceive of the particles of matter arriving at a state of division so minute as to exempt them from mechanical force. It has been found, however, that the latter opinion coincides with experiment as far as we have followed it, and that it promises to furnish the chemist with one general law, within whose pale all the substances with which he is acquainted will fall, and by which all the facts which experiment affords, will be generalized and reduced to systematic order. To this law the name of the Atomic theory has been given by Dr. Dalton; and it is to this theory, as originally developed by Dr. Dalton, that the first part of this chapter will be devoted; in the sequel we shall consider the various additions and modifications of subsequent authors.

The atomic hypothesis was first made use of in chemical investigation by Mr. Higgins of Dublin. That gentleman, in his "Comparative View of the Phlogistic and Anti-phlogistic Theories," published in 1789, observes that "in volatile vitriolic acid a single ultimate particle of sulphur is intimately united only to a particle of dephlogisticated air; and that in perfect vitriolic acid every single particle of sulphur is united to two of dephlogisticated air, being the quantity necessary to saturation."

* p. 227. "And," says Dr. Turner,* "he reasons in the same way concerning the constitution of water, and the compounds of nitrogen and oxygen." But these remarks, although prior to Dr. Dalton's discovery, are so crude and so difficult to be comprehended, that they cannot possibly be said to affect the originality of that chemist's important discovery. If there was any meaning in them, it appears to have been unnoticed not only by the world, but by Mr. Higgins himself; and so little was the volume containing them known to the world, that Dr. Dalton had never seen it previous to the publication of his opinions.

Having premised thus much, I shall now proceed to the theory of atoms, as developed by Dr. Dalton.

Law 1st. All bodies are composed of spherical atoms.*

Law 2nd. When two substances combine, the atoms of those bodies unite.

Law 3rd. The atoms of different bodies differ in weight and size.

* The word *atom* is derived from α, and τεμνειν, to cut. The word means, incapable of being cut or divided.

The first law is not capable of mathematical demonstration, and we are therefore to receive it as an assumption, which we are at liberty to discard as it shall be found incompatible with the result of experiment. In the present state of chemical science, it is found not only concordant with the many new facts which the

investigations of philosophers are daily bringing to light, but that it materially facilitates the analyst in ascertaining the composition of several classes of substances. I allude more particularly to the discovery of Professor Mitscherlich, of the isomorphism* of several substances.

* From ἴσος equal, μορφὴ form.

The fact has long been established by M. Haüy, that substances assume a particular form in crystallizing; and, provided circumstances are favourable, this form is always the same. Thus we know the forms in which almost every salt will crystallize, if the crystallization be allowed to proceed gradually: and M. Haüy concluded, that the form of most crystals(*s*) indicated the composition. This law, which was quite axiomatic with M. Haüy, has been proved by Professor Mitscherlich to be false. The researches of this philosopher(*t*) show that certain substances assume the same crystalline form, and that this similarity of form often leads to a similar correspondence in atomic constitution. This law holds good in many cases, more especially in the following groups:

(*s*) Haüy considered this law as holding good in all crystals excepting the cube, the tetrahedron, the regular octohedron, and the rhombic dodecahedron, besides some others included in the tessular system of Mohs.

(*t*) Annal. de Chimie et Phys. tom. xiv. xix. xxiv.; and Thomson's Annals. vol. xi. 262; xiii. 126.

ISOMORPHOUS SUBSTANCES.

PHOSPHATES, BIPHOSPHATES, ARSENIATES, AND BINARSENIATES.

Name of salt.	Isomorphous salt.
Phosphate of soda.	Arseniate of soda.
Biphosphate of soda.	Binarseniate of soda.
Phosphate of ammonia.	Arseniate of ammonia.
Biphosphate of ammonia.	Binarseniate of ammonia.

In the above class, the arseniates and phosphates agree in form and in composition, possessing the same number of equivalents of acid, of base, and even of water of crystallization.

There are, besides these, several others which were drawn up and read to the British Association, by Professor Johnstone, of Durham, in his Report on Chemistry.

1.
Silver
Gold

2.
Arsenious Acid, in its unusual form
Sesquioxide of Antimony

3.
Alumina
Peroxide of Iron

4.
Salts of
Phosphoric Acid
Arsenic Acid

5.
Salts of
Sulphuric Acid
Selenic Acid
Chromic Acid
Manganic Acid

6.
Salts of
Perchloric Acid
Permanganic Acid

7.
Salts of
Potassa
Ammonia with 1 eq. of water

8.
Salts of
Soda
Oxide of Silver

9.
Salts of
Baryta
Strontia
Lime (in Arragonite)
Protoxide of Lead

10.

Salts of
Lime
Magnesia
Protoxide of Iron
  Manganese
  Zinc
  Nickel
  Cobalt
Protoxide of Copper
  Lead (in Plumbo-Calcite)

11.

Salts of
Alumina
Peroxide of Iron
Oxide of Chromium
Sesquioxide of Manganese

These facts tend very much to establish the law of the atomic constitution of bodies: the analogy of these isomorphous substances may be carried still farther. Not only is the arseniate similar in form and constitution to the phosphate, but the arsenic and phosphoric acids are also similar in composition: and the arsenic and phosphorus emit the same odour when heated, and are both in the same electrical class.

The argument deducible from the laws of isomorphism in favour of the atomic constitution is very satisfactory, although not amounting to a demonstration. If substances which assume the same form are similar in their composition, what inference can be drawn but that they are composed of the same number of similar atoms, which atoms are similarly arranged? These are the only facts that I am acquainted with, which render it probable that the hypothesis of the first law of the atomic theory is correct.

I am aware that I have said nothing concerning the spherical form of the atoms; the assumption is hypothetical, but warranted by analogy. The well-known natural law, "that all substances will assume, under favourable circumstances, the spherical form," certainly warrants the opinion that the atoms of bodies are spherical. Dr. Dalton has invented certain symbols to illustrate this fact, and also to afford an idea of the manner in which he supposes bodies may combine.

⊙ Hydrogen. ○ Oxygen.
⊙ Nitrogen. ● Carbon.

BINARY COMPOUNDS.

⦶ ⊙ Water.
○ ● Carbonic oxide.

TERNARY COMPOUNDS.

○·⊙ ○ Binoxide of hydrogen.
○ ● ○ Carbonic acid.
&c. &c. &c.

The elementary bodies (see table at the end of this work) are called by Dr. Dalton, primary bodies, as composed of one atom only; those of two atoms, he denominates binary; those of three, ternary; of four, quaternary, &c. &c., as above.

The demonstration of the second law immediately follows that of the first; for if bodies are composed of atoms, it must of necessity be granted, that if two of these bodies combine

and form one, the various parts which compose them must combine also. For if A and B combine to form C, and in every part of C a portion of A and B be detected, it follows that C is composed of the particles of A and B. The principal evidence in favour of the second law is, the combination of substances in definite proportions; for we cannot suppose that two bodies (composed of atoms) can unite always in the same proportion, unless the atoms of those bodies combine. As, however, I shall have more to say upon this law in the sequel, when considering the ingenious modification of it by Dr. Prout, in his Bridgewater Treatise, I shall now proceed to the third law of Dr. Dalton.

The third law asserts, "that the atoms of different bodies differ in weight and size." It may seem rather paradoxical, after having asserted that the constituent atoms or ultimate particles of matter are so minute as to be indivisable (as the word implies), to say that they differ in weight and size: but, in reality, this law is more susceptible of proof than either of the former.

It has been demonstrated by experiment, that bodies combine in definite proportions; and it has been partially proved that they are composed of atoms, and that these atoms combine: we immediately perceive, therefore,

that the combining proportions, and the weight of the atom will be the same. Now, although chemists have not yet arrived at that nicety of calculation which will enable them to give the exact weight of each atom, yet they are in possession of a formula for ascertaining their specific weight, or the relative weight, the atom of one body being compared with that of another.

Dr. Thomson has proved the minuteness of these ultimate atoms to be so small, that $\frac{1}{1,400,000,000}$th of a grain of gold constitutes a considerable number of the atoms of that substance. The reasoning is very beautiful by which that eminent Professor arrived at this conclusion:—Gold leaf has been proved by experiment to be sufficiently malleable to present a surface of 50.7 square inches from one grain weight of the metal. Now the 1000th part of a linear inch is visible through a common pocket glass. A square inch is divisible into a million of parts, and visible through a common microscope. Hence, when gold is reduced to the thinness of gold-leaf, $\frac{1}{50,700,000}$ is to be distinguished by the eye. Reaumur also has proved, that one grain of gold of the thinness which it is upon silver wire, will cover an area of 1400 square inches. It is plain, therefore, that $\frac{1}{1,400,000,000}$th part of a grain is visible through a common glass.

I cannot refrain from quoting an experiment

in connexion with this subject, immediately following the former in Dr. Thomson's system.

"I dissolved one grain of dry nitrate of lead in 500.000 grains of water, and after having agitated the solution, passed through it a current of sulphurated hydrogen gas. The whole liquid became sensibly discoloured. Now we may consider a grain of water as equivalent to about a drop of that liquid. And a drop may be easily so spread out, as to cover a square inch of surface. And under an ordinary microscope, the $\frac{1}{1,000,000}$ of a square inch may be distinguished by the eye; the water, therefore, could be divided into 500,000,000,000 parts, every one of which contained some lead united to sulphur. But the lead in a grain of nitrate of lead, weighs only 0.62 gr. It is obvious, therefore, that an atom of lead cannot weigh more than $\frac{1}{310,000,000,000}$th of a grain. While the atom of sulphur (for the lead was in combination with the sulphur, which rendered it visible) cannot weigh more than $\frac{1}{2015,000,000,000}$ of a grain.

"The size of these very minute quantities of matter might easily be computed; but it would be so small as to render it impossible for us to form any adequate estimate of it. For example, the bulk of the portion of lead which may be rendered visible by the process above described, would be only $\frac{1}{888,492,000,000,000}$ of a cubic inch."

From these able experiments, we at once perceive that it would be useless to attempt to obtain the exact weight of each of these atoms; it is manifest, that the inconceivably small particles mentioned in the above experiment, could be the atoms of the substance, because they were susceptible of further division by mechanical agency. If chemists could arrive at the exact weights of these atoms, the science of chemistry would be as purely mathematical as astronomy, or any of those usually designated the higher mathematics. But notwithstanding the apparent impossibility of attaining the exact weight, the relative weight of the atoms is exactly ascertained, and this is found to bear a striking relation to the specific gravity of the respective elements in vapour.(*u*)

The method of obtaining the relative weight of the atoms will be of course to ascertain the combining proportion of the element, for they must inevitably be the same.(*x*) The weight

(*u*) This subject will again be adverted to in the 4th chapter.

(*x*) This subject is one of great difficulty to students in chemistry, and it is here where the danger is of confounding theory with facts. The combining proportion is that real proportion in which one body combines with another to form a third: this is found by analysis to be always the same; so that if we take 100 parts of C, and find by analysis that they are made up of 60 of A, and 40 of B, provided our

of the atom (or atomic weight, as it is generally denominated) is a deduction from the combining proportion, so that by the very means we adopt to obtain the combining proportion, we in fact ascertain the atomic weight, always keeping in mind that the combining proportion

analysis be correct, these proportions will always be the same, and A and B, uniting 60 of the one and 40 of the other, will be always from C. But as this mode of calculating the composition of any compound body has been found very difficult to keep in remembrance, chemists have agreed to refer all substances to a scale where one is arbitrarily made unity. In order to establish this unity, we must first ascertain, by analysis, of some substance containing the element we regard as unity, in what proportion it combines. For example, oxygen and hydrogen combine to form water : we agree to consider this compound as formed of one atom of each. We then analyze the water, and we find that it is composed of eight parts by weight of oxygen, and one of hydrogen; therefore, if we make hydrogen unity, its representative number will be 1; if oxygen is unity, hydrogen must be 0.125. This is in fact the composition of water expressed in relative numbers.

The theory is thus deduced. By law 2nd. it is proved that all bodies combining, combine by means of their atoms. We have proved that water is composed of 8 parts by weight of one element, and one of another. We have also agreed to consider water as composed of one atom of each of its constituents, oxygen and hydrogen. Therefore it follows that the weight of the atom of oxygen will be to that of hydrogen, as 8 to 1. Consequently, the theoretic weight of the atom of any substance is the same as the "combining proportion," as proved by experiment.

is a demonstration; while the atomic weight is a theory which may stand or fall without at all interfering with the truth of the laws regulating the combining proportions. Having now gone over the arguments which may be adduced in favour of the three laws abovementioned, it only remains for me to give the objections to their universal acceptation.

Dr. Dalton, in advocating the atomic theory, founds his principal argument upon the law of multiple proportions.(*y*) This law, the reader will recollect, asserted that bodies combining in more proportions than one, always followed the rules of arithmetical progression, 1, 2, 3, 4, 5, &c.; consequently, we have in this a strong circumstantial proof, that the substances combining in such very regular proportions, combined by means of their ultimate atoms; for when we take into consideration the fact of bodies crystallizing, under ordinary circumstances, in their particular crystals, and added to this, their combining in multiple proportion, it seems almost impossible for any person to doubt of their being atomically constituted; for if they are not so constituted, it is difficult to conceive what law or force that can be, which attaches the *infinitely divisible* particles together to form

(*y*) See page 96.

always the same shape, and to combine invariably in the same proportion.

How satisfactory soever this evidence may appear, there has been some little doubt thrown upon the subject by a recent discovery,(z) viz. that bodies combining in more proportions than one, sometimes combine in another progression—1, 1½, 2, 2½, 3, 3½, &c.

In the preceding case we considered the law of multiples, which progressed in whole numbers, as confirmatory of the atomic theory; we are, it would seem, obliged to consider this as negative of the same theory.

In the former example we thus stated the fact: there being five compounds of oxygen and nitrogen, (*a*) we considered them as thus constituted:

Protoxide .	$\dot{N}$	or 1 atom of nitrogen, & 1 atom of oxygen.
Deutoxide .	$\ddot{N}$	or 1 atom of nitrogen, & 2 atoms of oxygen.
Hyponitrous acid	$\dddot{N}$	or 1 atom of nitrogen, & 3 atoms of oxygen.
Nitrous acid .	$\ddddot{N}$	or 1 atom of nitrogen, & 4 atoms of oxygen.
Nitric acid .	$\overset{\cdot\cdot\cdot\cdot\cdot}{N}$	or 1 atom of nitrogen, & 5 atoms of oxygen.

So we must now regard the second example, stated similarly, as thus constituted:

		Iron.		Oxygen.
Protoxide of iron .	Fe + O	or 1 atom	+	1 atom.
Peroxide . .	Fe + 1½O	or 1 atom	+	1½ atom.

(z) See page 97. (*a*) See page 96.

		Manganese.	Oxygen.
Protoxide of Manganese	$Mn + O$	or 1 atom	$+$ 1 atom.
Sesquioxide . .	$Mn + 1\frac{1}{2}O$	or 1 atom	$+$ $1\frac{1}{2}$ atom.
Binoxide . . .	$Mn + 2O$	or 1 atom	$+$ 2 atoms.

		Phosphorus.	Oxygen.
Hypophosphorous acid	$P + \frac{1}{2}O$	or 1 atom	$+$ $\frac{1}{2}$ atom.
Phosphorous acid .	$P + 1\frac{1}{2}O$	or 1 atom	$+$ $1\frac{1}{2}$ atom.
Phosphoric acid .	$P + 2\frac{1}{2}O$	or 1 atom	$+$ $2\frac{1}{2}$ atoms.

If this be the exact fact, then the atomic theory can no longer be supported; because the very name of *half an atom* is inadmissible, being in direct opposition to the word atom itself, for the word signifies, not to be divided.(*b*) There are, however, two methods of removing this difficulty:—First, by supposing the discrepancies to be mechanical admixtures, and not chemical compounds. And secondly, by describing their constitution in whole numbers, without altering at all the fact. We have very good grounds for considering these anomalous compounds as mechanical, and not chemical. In the first place, those of them that form oxides, rarely, if ever, unite with acids to form permanent salts. As an example, persulphate of iron is a salt of this order, but it never even crystallizes; in fact, it is no chemical salt at all. And in the second place, their very composition has an unfortunate coincidence upon the face

(*b*) See page 114.

of it. For if we state the composition, we shall perceive that a mechanical admixture of the other oxides of the same substance would produce a similar result:

1 atom of protoxide of mang. is composed of	mang. 27.7	& oxygen	8.
. sesquioxide	27.7	.	12.
. binoxide	27.7	.	16.

The combining proportions will be—

Protoxide of manganese $27.7 + 8 = 35.7.$
Sesquioxide . . . $27.7 + 12 = 39.7.$
Binoxide . . . $27.7 + 16 = 43.7.$

Now if an atom of protoxide be added to an atom of binoxide, we shall produce two atoms of sesquioxide:

$$35.7 + 43.7 = 79.4,$$

which $\frac{79.4}{2} = 39.7$, or the combining proportion of the sesquioxide.

We may also take the compounds of phosphorus and oxygen, as enumerated above, and we shall find they are similarly constituted.

	Parts.		Parts.	
Hypophosphorous acid is composed of	15.7	of phos. &	4	of oxygen.
Phosphorous acid . . .	15.7	.	12	.
Phosphoric acid . . .	15.7	.	20	.

The combining proportions are—

Hypophosphorous acid $15.7 + 4 = 19.7.$
Phosphorous acid . $15.7 + 12 = 27.7.$
Phosphoric acid . $15.7 + 20 = 35.7.$

If the hypophosphorous and phosphoric acids be added together, we have two atoms of phosphorous acids:

$$19.7 + 35.7 = 55.4;$$

which $\frac{55.4}{2} = 27.7$, or one proportion of phosphorous acid. But it would be of course an assumption not quite warranted by experiment to allow such a theory as this: all I mean to show is, that the facts may be explained so as not at all to militate against the atomic theory.

The second method of accounting for these compounds is, by doubling the combining proportions of both constituents; we should, by this means, get rid of the discrepancy. For example:

Protoxide of iron 28, iron + 8 oxygen
Peroxide of iron 56, iron + 28 oxgen,

instead of

Peroxide of iron 28, iron + 12 oxygen.

In this manner the facts may be reconciled, so that instead of 1 atom of A, and 1 atom and a half of B, we have 2 atoms of one, and 3 atoms of the other. The same mode of proceeding will render the compounds of phosphorus agreeable to the atomic theory.

Hypophosphorous acid	31.4 of phosphorus + 8.
Phosphorous acid .	31.4 of phosphorus + 24.
Phosphoric acid .	31.4 of phosphorus + 40.

The compounds of phosphorus and oxygen intervening between the first and second above-mentioned, and the second and third, no doubt exist, but have not as yet been discovered.

From these facts it is but fair to conclude that these compounds are anomalous, and are to be referred to the same cause, and be considered in the light of a *lusus naturæ*. There is a remarkable analogy between the animal creation and the formation of these compounds. We are aware of the animal called a mule, a cross between the horse and the ass; and again, of the bird called the mule-canary, a mixture of the common canary and the goldfinch: but these animals invariably refuse to propagate their particular species—in fact, they are not endowed with the power of so doing. So it is with the mixtures of protoxides and peroxides; they form an intermediate compound, partaking of the properties of both constituents, but refuse for the most part to form any combinations with other bodies.

I have now come to the conclusion of the atomic theory of Dr. Dalton, and shall briefly consider the modifications that have been proposed.

The electro-chemical theory I have already explained. It endows the atoms with electrical powers, and accounts for their combining by

means of these powers. Having gone over this once, it will be unnecessary to say more upon the subject.

The next modification of the atomic theory is that most ingenious and valuable one which has been given to the world by Dr. Prout,(*c*) after "twenty years' attentive consideration." Dr. Prout commences by demonstrating the extreme minute divisibility of matter. "But," says he, "there cannot be the least doubt, that matter, as it exists in the world around us, is composed of ultimate particles or molecules, incapable of further division or change." The shape of the molecules or ultimate particles is next considered: some have maintained the shape of the atom or molecule to be the miniature of the aggregate mass; but the Doctor rejects this opinion, and considers, with Dr. Dalton, the atoms of all bodies to be spherical. Considering the molecules to be spheres, with what powers are we to suppose them endowed in order to cohere, and to assume the various symmetrical forms we observe among natural bodies? Prout first supposes a simple, mutual attraction among the molecules; "but this is inadequate to explain the phenomena." He next supposes the ultimate molecules of matter to be endowed with an attractive force at the point

(*c*) Bridgewater Treatise.

corresponding to the north pole, and a repulsive force at the opposite point; consequently the molecules will arrange themselves longitudinally. Again: the spheres are supposed to be endowed with similar forces at two other points, corresponding to ultimate points of the equatorial line. These forces may be denominated polarizing and equatorial forces. The former of these forces, arranging the particles longitudinally, would give rise to a gaseous body: the second, horizontally, a liquid. And now it only remains to examine into the nature of solids.(*d*) It will be remembered that we have two more points in the sphere as yet unnoticed. The line already mentioned, drawn from the north to the south pole, is one line; the equator is another. Now, suppose a circle similar to the equator upon globes to be drawn upon the spheroidal molecule; the equatorial line before mentioned would divide this circle into two semicircles, and this line would be an axis. Take a point in the equator, let another axis pass at right angles to the former through the centre of

Polarizing forces.

Formation of gases, liquids, and solids.

(*d*) These arrangements I have added, because I thought they were deducible from the language. The Doctor says, "To form a third dimension, or to constitute a solid," &c. when speaking of this third arrangement; I consequently inferred, that the two former arrangements were the one for liquids, the other for gases, as I have stated.

the sphere, we have then two more points equi-distant from the two former equatorial points. Let one of these points be attractive, the other repulsive, similar to the others; the result will be a solid cube, (if there are molecules sufficient,) or "some figure deducible from a cube." "In this way," says Dr. Prout, "by assuming certain attractive and repulsive points upon our spheres as appropriate parts of their superficies, it is not difficult to conceive them capable in different instances of forming aggregates of any shape whatever."

Formation of solids.

This is the hypothetical view taken by Dr. Prout. Some of the arguments in support of it are the following:—

Chemical and cohesive forces.

The chief argument is one taken from the striking analogy between the above laws, and the forces which actually exist in nature. Dr. Prout proposes to call the one force of the molecule, its *chemical* axis,(*e*) or polarity; the other, its *cohesive* axis or polarity; and by comparing these with the electric and magnetic forces, he finds the same relation to exist between the laws he has laid down for mole-

Analogy between the forces, and electricity, and magnetism.

(*e*) At page 53 of the Treatise, Dr. P. defines the chemical and cohesive powers in the following manner: "One which we have denominated *chemical* polarity, existing between molecule and molecule, and chiefly between molecules of *different* matter; another denominated *cohesive* polarity, determining under certain circumstances the cohesion of the molecules of the same matter."

cular combination, and the electric and magnetic agencies of nature.

The reader who wishes to follow this part of the subject, will find himself amply repaid by referring to that admirable volume from which these remarks have been taken. The analogy of the forces I shall take for granted, as I have not space to give the able arguments Dr. Prout has brought forward in support of his opinions. We will then consider as demonstrated, the following hypotheses:

Hypotheses.

1. That bodies are composed of ultimate molecules, (*i.e.* atoms,) each of which molecules are spherical in form, and possessed of two polarities, a *chemical* and a *cohesive*.

2. That the chemical and cohesive polarities exist at right angles to each other in the same molecule.

3. That the polarities of these molecules bear the same relation to each other, as electricity and magnetism.

Combination of molecules.

Dr. Prout next proceeds to show how molecules may combine; sometimes chemically, and sometimes cohesively. In the instance of ice, we may suppose them combined chemically; as the ice liquefies, the molecules assume their cohesive combination. These forces (chemical and cohesive) are very analogous, affording a striking resemblance, in this

instance, with those of electricity and magnetism.

Phenomena of dimorphism how explained.

The phenomena of dimorphism are also very easily explained by the hypothesis. Dimorphism is the power which some substances have of crystallizing in the two different forms; and certainly no evidence can be more satisfactory in favour of the new theory, than that the substance at one time assuming one form, should at another assume a different one. For how can it be explained, unless we suppose it to be occasioned by a different arrangement of the particles of the substance?

In gases, oxygen for example, every self-repulsive molecule (*f*) consists of at least two molecules, united cohesively and acting in concert: for it is evident that the molecules cannot exist without forming a combination, either chemically or cohesively. From other data, Dr. Prout concludes that the self-repulsive molecules of most gases are *double*, or perhaps much more compounded.

I shall give an example of the laws of combination from Dr. Prout's Treatise. "Precisely the same laws of union may be supposed to prevail among the molecules of bodies themselves, as they actually exist around us. Thus, let us take the crystal of oxalic acid, as an

(*f*) Not ultimate molecule—*that* is indivisible.

instance for illustration. This acid is composed, according to the present language of chemists, of two molecules of carbon, and three of oxygen, which, by combining, form the acid; while, to complete the compound molecule, and to adapt it for crystallization, three molecules of water are required to be somehow associated with each of the molecules of the acid. Now, in this case we suppose that the two molecules of carbon, (each of which is perhaps already made up of several sub-molecules,) are associated together into one symmetrical super-molecule; that the three molecules of oxygen, associated in a similar manner, are then combined *chemically* with the super-molecule of carbon, and thus form by their union a molecule of oxalic acid; finally, that the three molecules of water are associated into one super-molecule, which unites *chemically* with the molecule of oxalic acid, and thus completes the molecule of the acid, as it actually exists in the crystalline form."

Constitution of oxalic acid, according to Dr. Prout.

With these remarks I shall conclude this very brief sketch of Dr. Prout's theory. It now only remains to inquire what are the advantages which would result from its adoption, and what are the disadvantages.

In the first place, we have a great support afforded to the electro-chemical theory; for if these chemical and cohesive axes are similar

in property to the more powerful agents of electricity and magnetism, they may, without much exaggeration, be declared identical.

Phenomena of isomerism how explained.

Secondly, the phenomena of isomerism(*g*) are explained very satisfactorily by the hypothesis. Isomeric bodies are bodies which are formed of the same constituents, and in the same proportions, yet produce compounds differing materially in properties from one another. The cyanic acids are in this situation. Here we have two acids differing in property, essentially yielding, upon analysis, precisely the same results; both affording 1 atom of oxygen, and 1 atom of cyanogen. One of these acids was first noticed by Wöhler, the other by Leibig. Dr. Turner has retained the names given to each of them by their discoverers, in order to prevent confusion. They differ remarkably in their properties, one (the cyanic) forming compounds totally different in character from the other (the fulminic,) the compounds of the last-mentioned being possessed of the most powerful detonating properties.

Fulminic and cyanic acid.

The constitution of these acids is—

	Cyanogen.
Cyanic acid	26.39, or 1 equivalent + oxygen 8 or 1 eq.
Fulminic acid	26.39, or 1 equivalent + oxygen 8 or 1 eq.

(*g*) Isomerism, (from ισος equal, μερος part) meaning a substance composed of equal and similar ingredients.

The only method of accounting for so remarkable a fact is, by assuming the atomic hypothesis of Dr. Prout. We can easily imagine that the atoms of these acids arrange themselves, at one time according to their chemical, and at another according to their cohesive polarities.

We must now consider what are the reasons which tend to retard the adoption of this theory.

The theory not supported by a sufficient number of facts.

1st. It is not supported by a sufficient number of facts. Before adopting any theory, we must not be taken with apparent advantages in the facility which its assumption will give for the explanation of many facts; but we must inquire upon what is the theory based: and this is only to be done by an appeal to universal, and not to particular phenomena. A theory which proposes to systematize the whole of any science, must of course be applied to the varied facts which that science may contain: unless this caution be attended to, we shall deduce hasty conclusions, supposing them to be general laws, while they ought to be regarded as singular coincidences.

The theories in chemistry have too often attested the truth of this observation: the phlogistic was one example, the anti-phlogistic another, the electro-chemical a third, all of which were supported by a few isolated facts;

but when universally applied, were found to be untenable.

The science of chemistry is so diversified, that it would be impossible for any man, even were he to devote a lifetime to the subject, to apply every single fact to a new theory: but it is in the power of any individual to test the verity of a new theory by application to the large groupes or classes into which chemical phenomena are divided; the want of these facts, which are the only evidence at all valid, I am afraid will very much retard the progress of the atomic hypothesis of Dr. Prout.

Dr. Prout's theory militates against the atomic weights now in use.

2nd. The assumption of Dr. Prout's theory would materially alter the list of atomic weights or combining proportions now in use. Now, although this objection may appear at first to be trivial and unnecessary, it will, if followed up, be found a very important one. It is no argument in favour of the list of atomic weights now in use, to say that they have been established for some time, and are, for the most part, allowed by chemists to be correct; because, if wrong, they ought immediately to be abandoned. But when our daily experience tends to corroborate the numbers in that list, and to manifest its great utility, the case becomes different; and it will be a matter of grave deliberation, whether we shall set aside a table of acknowledged correctness and utility,

to substitute one which is as yet supported only by ingenious arguments, and *very remarkable* coincidental analogies. To prove that the new theory will effect this change, I quote Dr. Prout's own words: "If the views, however, which we have taken be correct, these numbers(*h*) do certainly not represent nature: for, as we have already stated, a strictly philosophical arrangement can be rationally founded only upon the volumes of bodies in a gaseous state; in which state, some common volume in all instances should be considered as molecular unity."

We must now conclude this most interesting part of chemistry. The atomic theory is certainly the only one capable of explaining the varied phenomena presenting themselves to our notice in the study of the science; and it is to be hoped, that the trifling objections to its universal acceptance will soon be removed, and chemistry claim for herself the enviable designation of a "mathematical science."

(*h*) Alluding to the list of combining proportions.

CHAPTER IV.

THE THEORY OF VOLUMES OF M. GAY LUSSAC.

In the preceding part of this work we have remarked, that bodies combining with one another, combine in definite proportions by weight. Thus, in the formation of water, 8 parts by weight of oxygen, combine with one part by weight of hydrogen. This law was noticed in 1807, by Dr. Dalton, and was immediately succeeded by another discovery * equally interesting—the combination of gases in equal proportions as regards their volumes.

* By M. Gay Lussac.

Composition of water by volume.

Thus, in the formation of water, M. Gay Lussac observed, that 100 measures (by volume) of oxygen, combined with 200 measures (by volume) of hydrogen. From this remarkable coincidence, Gay Lussac was led to analyze other gaseous compounds, always meeting with analogous results.

The fluoborate, muriate, and carbonate of ammonia, first attracted his attention. These substances being compounded of two gaseous bodies, were easily examined synthetically, by mixing the gases in certain proportions.(*i*) By this means, 100 volumes of ammonia were found to combine with 100 of muriatic (or hydrochloric) acid to form muriate of ammonia, which was found to be the only compound formed by the union of muriatic acid and ammonia. The fluoboric and carbonic united with ammonia in two proportions.

Composition of muriate of ammonia by volume.

100 volumes of fluoboric acid, with	100 of ammonia.
100 . . ditto . .	200 ditto.
100 volumes of carbonic acid, with	100 ditto.
100 . . ditto . .	200 ditto.

(*i*) Chemists have two modes of arriving at the composition of any substance—synthesis and analysis. By synthesis (derived from *συν* and *τιθημι*) is meant the union of the two substances A and B to form C. By analysis, the separation of C into A and B. Thus, we have two ways of proving the alleged composition to be correct. For example: the synthetic proof of the composition of water is ascertained by mixing together 8 parts by weight of oxygen, and one of hydrogen; or, by volume, 100 measures of oxygen, and 200 of hydrogen; when these gases are brought in contact, under certain circumstances they will unite, and thus give us synthetic demonstration of the composition of water. The analytic proof is thus obtained: water is subjected to the agency of galvanism; it is by this means resolved into oxygen and hydrogen: thus we obtain analytic evidence of its composition.

Vaporized solids.

The next series of substances submitted to examination by M. Gay Lussac, were bodies composed of vaporized solids, such as sulphuretted hydrogen and hydriodic acid; the composition of these substances, as ascertained by experiment, fully agrees with laws of combination in volumes by definite proportions.

600 hydrogen + 100 vap. of sulph. form sulphuretted hydrogen.
100 ditto . + 100 vap. of iodine form hydriodic acid.

Volumes of compound gases bear a simple ratio to their elements.

In the course of these experiments, Gay Lussac remarked another coincidence, namely, that the volumes of compound gases bear a very simple ratio to the volumes of their elements; this fact is exemplified in the following table, taken from Dr. Turner, p. 229.

Volumes of Elements.			Volumes of resulting Compounds.
100 Nitrogen	+	300 Hydrogen yield	200 Ammonia.
50 Oxygen	+	100 Hydrogen . .	100 Water.
50 Oxygen	+	100 Nitrogen . .	100 Protoxide of nitrogen.
100 Sulphur	+	600 Hydrogen . .	600 Hydrosulphuric acid.
100 Sulphur	+	600 Oxygen . .	600 Sulphurous acid.
100 Chlorine	+	100 Hydrogen . .	200 Hydrochloric acid.
100 Iodine	+	100 Hydrogen . .	200 Hydriodic acid.
100 Bromine	+	100 Hydrogen . .	200 Hydrobromic acid.
100 Cyanogen	+	100 Hydrogen . .	200 Hydrocyanic acid.
100 Oxygen	+	100 Nitrogen . .	200 Binoxide of nitrogen.

The laws of combination in multiple proportions, may be exemplified with the same facility when bodies unite by volume, as when

they unite by weight. Thus, for example, the compounds of nitrogen enumerated at page 125, will combine by volume in definite proportions, affording resulting compounds which obey the same law of geometrical progression.

	Nitrogen.		Oxygen.
Protoxide of nitrogen is composed of	100	+	50.
Deutoxide of nitrogen . . .	100	+	100, or 50 × 2.
Hyponitrous acid . . .	100	+	150, or 50 × 3.
Nitrous acid . . .	100	+	200, or 50 × 4.
Nitric acid . . .	100	+	250, or 50 × 5.

Law of multiples demonstrable by volume.

Thus we perceive, that 1, 2, 3, 4, 5, is the same ratio in which these substances combine by weight. We may also infer, that the second law of multiple proportions, 1, $1\frac{1}{2}$, 2, $2\frac{1}{2}$, &c. is also demonstrable by this method.

The law of combination by volume may be extended to the vapours of all those substances which exist, or can be made to exist, in vapour: and it is further observed, that the specific gravities of these compounds is deducible by a very easy formula, when the atomic weight of the compound is ascertained, as well as the combination by volume, and the amount of condensation. Thus, the following table (taken from Dr. Turner) gives us the combining proportion of the substances by volume and by weight, together with their specific gravities, from which we may deduce a theoretic formula almost infallible.

Gases and Vapours.	Specific Gravities.		Chemical Equivalents.	
	Air as 1.	Hydrogen as 1.	By Vol.	By Weight.
Hydrogen . . .	0·0690	1·00	100	1·00
Nitrogen . .	0·9727	14·12	100	14·15
Chlorine . . .	2·4700	35·84	100	35·42
Carbon (hypothetical)	0·4215	6·12	100	6·12
Iodine	8·7011	126·30	100	126·30
Bromine . .	5·3930	78·40	100	78·40
Water . . .	0·6202	9·00	100	9·00
Alcohol . . .	1·6202	23·24	100	23·25
Sulphuric ether . .	2·5822	37·50	100	37·50
Light carburetted hydrogen . .	0·5595	8·12	100	8·12
Olefiant gas . .	0·9810	14·24	100	14·24
Carbonic oxide .	0·9727	14·12	100	14·12
Carbonic acid . .	1·5239	22·12	100	22·12
Protoxide of nitrogen	1·5239	22·12	100	22·15
Sulphurous acid .	2·2105	32·10	100	32·10
Sulphuric acid (anhydrous) . . .	2·7617	40·10	100	40·10
Cyanogen . .	1·8157	26·35	100	26·35
Hydrosulphuric acid .	1·1770	17·10	100	7·10
Binoxide of nitrogen	1·0377	15·06	200	30·15
Mercury . . .	6·9690	101·00	200	202·00
Ammonia . .	0·5898	8·56	200	17·15
Hydrochloric acid .	1·2695	18·42	200	36·42
Hydriodic acid .	4·3850	63·63	200	127·26
Hydrobromic acid .	2·7310	39·71	200	79·40
Hydrocyanic acid .	0·9423	13·67	200	27·35
Arsenuretted hydrogen	2·6950	39·20	200	78·20
Sesquichloride of arsenic	6·2950	91·36	200	181·66
Sesquiodide of arsenic	15.6400	227·00	200	454·28
Protochloride of mercury	8·2040	119·00	200	237·42
Bichloride of mercury	9·4390	137·00	200	272·84
Bromide of mercury .	9·6650	140·26	200	280·40
Bibromide of mercury	12·3620	179·40	200	358·80
Biniodide of mercury .	15·6700	227·40	200	454·52
Oxygen . . .	1·1025	16·00	50	8·00
Arsenious acid . .	13·6695	198·4	50	99·40
Phosphorus . .	4·3273	62·8	25	15·70
Arsenic . . .	10·3620	150·8	25	37·7
Sulphur . . .	6·6480	96·48	16·66	16·10
Bisulphuret of mercury	5·3840	78·10	33·33	234·18

From the preceding table it will immediately be perceived, that the uniformity of

the ratio of the combining substances is much greater when they unite by volume, than it is when the union is made by weight. It will also be perceived, that the chemical equivalent in combining proportions of many of the substances is the same; the first 18 being 100, the next 15 being 200.(*k*)

Application of the theory of volumes.

We now come to the most important part of the theory of volumes—the method of

(*k*) "The identity in the equivalent volumes," says Dr. Turner, "of the elementary gases, hydrogen, nitrogen, and chlorine, led to the notion that the equivalent volumes of most other elements, such as carbon, sulphur and phosphorus, might also be identical. *Assuming* that identity, the specific gravity which those elements ought to have when gaseous may easily be calculated. Thus, taking 1, 6·12, and 16·1 as the equivalents of hydrogen, carbon, and sulphur, then will their specific gravities in the gaseous state, combining volumes being supposed equal, be in the ratio of 1, 6·12, and 16·1. This method, by which the hypothetical specific gravity of carbon, as stated in the table, was obtained, was first indicated by Dr. Prout. (An. of Phil. vi. 321.) But though such hypothetical numbers may sometimes be used for the convenience of expressing the relation of uniting substances by measure, recent facts show how dangerous it would be to confide in them; for by the table it appears that the equivalent volume of sulphurous vapour is one sixth of that of hydrogen, which renders the specific gravity of the vapour of sulphur six times greater than the hypothetical number. Similar deviation is observable in phosphorus, arsenic, and mercury. In these cases, the real specific gravity of a vapour is as much greater than the hypothetical as its equivalent volume is less than that of hydrogen."

deducing from the facts above stated, the specific gravity of the combining element.

In order to understand this process satisfactorily, we will first recapitulate the data from which this conclusion is deducible.

1. The combining proportion, or atomic weight of the element, is satisfactorily ascertained both by volume and by weight.

2. The law of multiple proportions has been shown to be demonstrable by the analysis of substances, whether they combine by volume or by weight.

Data furnished by the theory of volumes.

3. It has been proved,(*l*) that when gases combine and form a compound retaining its aeriform condition, the combination is often attended by a condensation (or a diminution in volume), which condensation bears a relational proportion to the volumes of the combining gases.

From these data we may conclude that the specific gravity of gases, combining in definite volumes, will be as the sum of the combining gases divided by the amount of condensation. For example: suppose the specific gravity of 100 volumes of oxygen gas to equal x. The specific gravity of 300 volumes compared with the same standard as the 100 volumes, will equal $3x$; and let the specific gravity of

(*l*) The reader is referred to Dr. Henry's Elements, or to any elementary treatise.

100 volumes of hydrogen equal a; consequently the specific gravity of a compound of 100 volumes of hydrogen, and 100 volumes of oxygen, combined without any condensation, will be $\frac{a+x}{2}$. Again: suppose the combination to be attended by a diminution in volume equal to y; then the specific gravity of the resulting compound will be $\frac{a+x}{2} \times y$.

These formulæ may be illustrated by examples.(*m*) The following table shows the composition of some aeriform compounds, and the amount of condensation of the volumes of the elements combining:

Gas or vapour.	Composition.		Resulting No. of vols.
	vols.	vols.	
Ammonia . . .	100 of nitrogen	+ 300 hydrogen	200
Water (in vapour) .	100 of hydrogen	+ 50 oxygen	100
Muriatic acid gas .	100 of hydrogen	+ 100 chlorine	200
Prussic acid . . .	100 of hydrogen	+ 100 cyanogen	200
Olefiant gas . . .	200 of hydrogen	+ 200 vap. of car.	100
Carbonic oxide . .	50 of oxygen	+ 100 vap. of car.	100
Protoxide of nitrogen	50 of oxygen	+ 100 nitrogen	100
Sulphurous acid .	100 of oxygen	+ 16.66 v. of sul.	100

(*m*) For example: Ammonia, as stated in the table, is composed of N100 + H300. Now, as 100 is the standard volume if there were no condensation, $\frac{9727 + 0.069 \times 3}{4}$, should give the sp. gr. of ammonia; but as the condensation is from 400 volumes to 200, *i. e.* from 2 to 1, we must multiply by the amount of condensation $\frac{0.9727 + 0.069 \times 3}{4} \times 2$ $= 0.5898$, the sp. gr. of ammonia.

From this table we perceive, that ammonia is composed of 100 volumes of nitrogen + 300 of hydrogen, and that these 400 volumes are condensed into 200 volumes. Now, from the preceding table of specific gravities, we learn that the specific gravity of nitrogen is 0.9727, and that the specific gravity of hydrogen is 0.069; consequently, the specific gravity of ammonia will be

$$\frac{0.9727 + \overline{0.069 \times 3}}{2} = \frac{1.1797}{2} = 0.5898.(n)$$

The formulæ of the other gases are similarly ascertained: they will be found to agree very nearly with the numbers ascertained by experiment. Dr. Prout also has noticed, that to find the specific gravity of any substance in the state of vapour, we have only to take half the specific gravity of oxygen, and multiply the product by the atomic weight of the particular substance; of course the atomic weight must be taken from the scale in which oxygen is unity. To give an example, the specific gravity of oxygen is 1.1111,(*o*) and $\frac{1.1111}{2} = 0.5555$.

(*n*) Taking 100 as the standard volume, it is evident that if we analyse 100 volumes of any gas, and add together the specific gravities of the constituents in the proportion which analysis points out, we shall obtain the true sp. gr. of the compound gas. (See Appendix.)

(*o*) This is not the correct sp. gr.; that given in the table is 1.1025. I have used the former in these calculations, because it is not finally determined what the exact sp. gr. of oxygen is, and the number 1.1111 is most commonly employed.

The atomic weight of iodine is 15.7875; the specific gravity of the vapour will be

$$15.7875 \times 0.5555 = 8.76995625;$$

or, if the specific gravity of oxygen be 1.1025, (see note,)

$$15.7875 \times 0.55125 = 8.70148125.(p)$$

This mode of calculating the specific gravity of an element, must of course depend for its correctness upon the atomic weight; consequently, by reversing the process, and making the specific gravity the basis, we may correct the atomic weight. For example: according to Dumas, the specific gravity of iodine in vapour is 8.716; this sum, divided by 5555,

Dr. Prout's method of calculating specific gravities.

(*p*) The specific gravity of iodine deduced by the method first stated, agrees better with this calculation. An argument confirming the opinion, that 1.1025 is a nearer approximation to the sp. gr. of oxygen than 1.1111.

The method alluded to is the following:—Hydrogen and iodine combine in equal volumes to form hydriodic acid, without any condensation; consequently, the sp. gr. of hydriodic acid in vapour will be the sum of the specific gravities of hydrogen, and of the vapour of iodine divided by 2. Then, by formula, (page 147,) supposing x to be the sp. gr. of iodine in vapour, and 0.069 that of hydrogen,

$$\frac{x + 0.069}{2} = \text{the sp. gr. of hydriodic acid}$$

gas; but this is found, by the experiments of M. Gay Lussac, to be 4.443.

Then $\dfrac{x + 0.069}{2} = 4.443$;

therefore, $x = \overline{4.443 - 0.069} \times 2$; *i.e.* 8.748. So that 8.748, should be the sp. gr. of iodine in vapour.

(half the specific gravity of oxygen), should give us the atomic weight. The result will be

$$\frac{8.716}{0.5555} = 15.69037 \text{ nearly.}(q)$$

This sum will be the atomic weight on the oxygen scale; we must therefore multiply by 8, to bring it to the hydrogen scale now in use:

$$15.69037 \times 8 = 125.52296.$$

The number deduced by Berzelius, from experiment, is 126.3. Perhaps the mean between the number calculated from these data, and that actually deduced from experiment by Berzelius, would be the most accurate.(r)

(q) Or, $\frac{8.716}{0.55125} \times 8 = 126.50536.$

This number approximates so nearly to the experiments of Berzelius, that it confirms the accuracy of the result obtained by that chemist, as well as the eorrectness of sp. gr. aseertained by Dumas.

(r) The process of calculating last mentioned might be materially shortened by the use of logarithms. We have only to find the logarithms of the two numbers, and their differenee must of course be the logarithm of the number wanted. For example:

The log. of the sp. gr. of iodine in vap. (*i. e.*) 8.716 is	0.9403172
The log. of half the sp. gr. of oxygen (0.5555) .	$\bar{1}.7446841$
The differenee is the log. of the atomic weight of iodine	1.1956331

To find the number answering to this log.	1.1956331
The next less tab. log. is the log. of 15690	1956229
1st remainder	102

The specific gravity is not correctly ascertained from these calculations; but we, by means of them, possess a power of comparing by two processes the results of experiment.

1. We have the atomic weight ascertained by experiment, and we find the specific gravity by either of two processes.

2. We have the specific gravity of any vapour ascertained by experiment, and we find the atomic weight.

By varying the process, and directly using hydrogen in place of oxygen, we have another

The difference is 277, and pro. pts. according to Hutton's tables are	3 for the part .	83
	2nd remainder	190
	7 nearest to part .	194
		4

So that the number is the same 15.69037. Using the logarithmic process, and taking the specific gravity of oxygen as stated in the table, we obtain the following result:

Log. of 8.716 .	0.9403172
Log. of .55125 .	$\bar{1}$.7413486
Log. differences .	1.1989686
Nearest tab. log. 15.811	1989593
	93
Prop. part 3.	82
	110
Prop. part 4.	110
	. . .

Making the number 15.81134, which is still nearer the Berzelian number.

mode of ascertaining the accuracy of any analysis. As we have all along made use of iodine, we will again take that element. If we multiply the atomic weight by the specific gravity of hydrogen, we shall have the specific gravity of iodine in vapour :

$$126.3 \times 0.069 = 8.7147.$$

Again : if we reverse this process, as we did when using oxygen in calculation, we shall be able to reverse the data with it similarly to oxygen.

According to M. Dumas, 8.716 is the specific gravity of iodine vapour. Then, by formula, page 149,

$$\frac{8.716}{0.069} = 126.32 \text{ nearly.}$$

The calculation by logarithms is the same.

Log. of 8.716	is	0.9403172
Log. of 0.069	.	$\bar{2}$.8388491
Log. diff.	.	2.1014681
Log. of 126.32	.	1014721
		40

From this relation between the atomic weight, the specific gravity and the combining volume, various theories have been deduced. The theory of volumes by M. Gay Lussac gave origin to these most interesting speculations ; the subsequent researches of Dr. Prout, and of Dumas, and Mitscherlich, have improved this branch

of chemical science. The field is an extensive one for minute investigation, and will, in all probability, be cultivated with increasing ardour, as chemistry approximates the mathematics.

CHAPTER V.

THE AGENTS OPPOSING CHEMICAL ATTRACTION.

There is in almost every science a variety of seeming paradoxes, which, like the mountains of the Alps, possess the character of impassability, until some Hannibal in philosophy undertakes the task, and speedily dispels the illusion. The three principal agents which oppose chemical attraction, under certain circumstances, are the very supporters of it. These three are—Light, Heat, and Electricity.

Light.—Two opinions relative to the nature of light have for a long time divided men of science. By some it is supposed to be a material substance—by others an immaterial principle; at all events it may be defined as a medium exclusively possessing the power of rendering any object visible.

Opinions of the ancients with regard to light.

The nature of light was an object of interesting speculation among ancient as well as modern philosophers. Empedocles and Plato maintained that vision was occasioned by particles evanescing from the surface of a body, coming in contact with other particles proceeding from the eye. Pythagoras considered that particles proceeding from bodies entered the pupil of the eye, and communicated the power of vision. And Aristotle defines light as the power of a transparent body, immaterial and differing from fire.

Malbranche and Sir Isaac Newton; their opinions on light.

Malbranche endeavours to draw an explicatory analogy between light and sound, and thereby to account for the phenomena exhibited by the former, as the effect of vibration. Sir Isaac Newton, however, was the first who gave a philosophical exposition of the nature of light. He considered it as a fluid emanating from the sun, a luminous body, in particles inconceivably minute; these particles, according to Sir Isaac, are emitted in right lines, and preserve their rectilinear direction till they are diverted from it by the agency of some extraneous cause. Inflection is produced by the attraction of some body which they approximate in their course. Refraction is occasioned by their penetrating through media of different densities. Reflection is brought about by the intervening opposition of some

reflecting body on which they infringe. And extinction is the consequence of their absorption by some substance into which they are directed.

Velocity of light.

The particles of light travel with a remarkable but progressive velocity, requiring some time for their transmission from place to place. By astronomical observations, the motion of light is estimated at 195.000 miles in a second of time. It is susceptible of decomposition, one ray being divided by the prism into seven coloured ones, which are denominated, violet, indigo, blue, green, yellow, orange, and red, because these colours are exhibited by them. The order in which they are placed is indicated by the word VIBGYOR, which is composed of the initial letter of each ray. Sir W. Herschel has observed the existence of another ray, which is invisible to the eye, but powerful in its effects. This is denominated the *calorific* ray, because the greatest power of heat is placed there. The position of this ray is in immediate ulterior juxtaposition to the red ray. Sir William also remarked that the heating power diminished as we advanced from the red ray to violet. In addition to the calorific ray, Dr. Wollaston discovered another ray, which differed in situation from the calorific, being in immediate ulterior juxtaposition to the violet ray. This he denomi-

Decomposition of light.

nated the chemical ray, because that in it resided the chemical power of light.(*s*)

The spectrum* appears then to be composed of seven coloured, and two colourless rays. We must now investigate the sources of light.

*Light decomposed by passing through a prism, is said to form a prismatic spectrum.

These may be divided into two classes: celestial, including the light which emanates from the sun and the fixed stars; and terrestrial, which is emitted by incandescent bodies, by phosphorescence, and by living animals. I cannot enter into each of these in the present work, and must therefore refer the reader to Dr. Turner, Professor Airy's Tracts, and Sir David Brewster. I have only to lay before the reader the effect of light as an antagonizing principle to chemical attraction. Light has been proved(*t*) to accompany chemical attraction; it may also be proved to support, if not to produce it; for when equal volumes of chlorine and hydrogen are placed in the same receiver, and exposed to agency of the sunbeam, they unite and form muriatic acid. It may seem, therefore, rather paradoxical to affirm that light is opposed to the same power which it attends at one time, and encourages at another: but such is

(*s*) Light has been supposed to be endowed with another ray possessed of magnetic power; but this, although supported by Dr. Morichini and Mrs. Somerville, has been completely disproved by M. M. Riess and Moser.

(*t*) Page 88.

the fact. *e.g.* When nitrate of silver is exposed to the light, in contact with the most minute portion of organic matter, the salt is decomposed, and a portion of the oxide of silver is reduced to the metallic state. It is upon this principle that the ink for marking linen is produced: this is one of the examples of philosophical speculations superseding elegance; for the appearance of an ugly daub of brown ink on the corner of a handkerchief, is by no means to be compared with the almost obsolete, but far more appropriate mark of coloured silk or cotton.

The action of light, in this and in every other instance, is to be attributed to the chemical ray of Dr. Wollaston. The *modus operandi* we are not acquainted with; perhaps it is the connecting link between light and electricity. The subject is one on which a speculation may be fairly hazarded. We now turn to the second agent opposing chemical attraction, viz. heat.

Heat.—The same division among scientific men is occasioned by heat, as we have noticed with regard to light; a similar interminable dispute about its materiality, and a similar paradoxical effect produced by its agency. Its immateriality is supported by Aristotle and the Peripatetic philosophers, among the ancients; and among the moderns, by Des

Cartes, Lord Bacon, Sir Isaac Newton, Macquer, Count Rumford, and Sir Humphry Davy. The contrary opinion is maintained by Epicurus, Democritus, Zeno, and Cicero, among the ancients; and by Homberg, Lemery the younger, and almost all modern philosophers. Its characteristics are, imponderability, capability of being transferred, reflection, deflection, radiation, absorption, conduction, and transmission. Its chemical powers in causing combination, I have already adverted to: I have now only to prove that it possesses a contrary power.

Characteristics of heat.

There is scarcely an individual compound substance in the whole range of chemical science that will not afford a demonstrative evidence of this. The fire gradually converts the coal into carbonic acid by union with the oxygen of the atmosphere; here is a new combination effected between two simple substances. There is a law, however, regulating the agency of heat: we are in possession of a means of ascertaining, by relative effects, the power of heat, which we call temperature, (see page 53.) By this means, we find that a certain temperature expands a solid; an increase of that temperature converts into a liquid; a greater increase converts the liquid into a vapour. This is the general effect of heat, but it is not universal; some solids are

Agency of heat.

decomposed without conversion into vapour; some immediately before the temperature reaches the boiling point of water. This last is the case when quodrichloride of nitrogen is exposed to a temperature above 200F. The question is, what is the rationale of these processes? does the heat change the position of the atoms? thus (see page 131,) rendering the solid liquid, and the liquid gaseous, in one case, and effect decomposition by imparting an electrical and repulsive power in another. These are questions which future researches must solve.

Electricity.—The last agent which belongs to the class of agents opposing chemical attraction, is electricity; or as, under another form, it is denominated galvanism. The history of both these, I have already in part adverted to; the remainder is so well known as to render its repetition useless. Electricity, as an agent opposed to chemical attraction, is the most powerful we possess. By galvanism, Sir H. Davy accomplished his brilliant discovery of the compound nature of the alkalies; in short, it is the only test on which reliance is to be placed of the elementary nature of any substance. So little is known concerning it, that a conjecture is with difficulty to be made as to what is the cause of its potent agency. Whether it throws the ulti-

mate particles into different electrical states, and so causes a separation of the constituents of compound substances, or by what means soever its object is effected, is at present a mystery.

Thus I have given a brief sketch of the agents opposing chemical attraction: it is imperfect, but where little is known, little can be said. My chief object in introducing this chapter, has been to direct any who may peruse this volume to investigate the subject upon which it treats.

APPENDIX.

[In the preceding Treatise, a limitation has been prescribed to "Chemical Science," inasmuch as one department alone has been investigated. Some of my readers, however, may not be acquainted with the principles and technicalities upon which the reasoning is founded: it is for their convenience that the following Appendix is written.]

CHEMISTRY.

Chemistry is a science which teaches the nature and properties of all bodies that can be subjected to examination. To ascertain the nature of any substance, the chemist has resource to analysis and synthesis, (see page 141). By analysis it has been proved, that all substances that have hitherto been discovered, are either elementary, or are resolvable into two or more elementary bodies. The elementary bodies are fifty-three in number, and are in general divided into three classes—gases, metals, and a third class, which is distinguished by its negative property of being neither gaseous nor metallic.

A gas is an agent existing, under ordinary circumstances, in an aeriform condition.

A metal is characterized by its power of conducting electricity, its opacity under all circumstances, and by a

peculiar lustre which can only be understood when designated "metallic lustre."

A body belonging to the third class is characterized by a total absence of all the properties of the two former classes: it is not aeriform; it is not a conductor of electricity; not opaque, but generally translucent, and has no metallic lustre. Thus the fifty-three elements are notified by their name to be of the nature of simple or elementary bodies. The properties are easily examined, and afford us the genius, species, characterizing difference, &c. of each.

CLASS I.

The first class (gases) contains four substances, which answer to the definition of a gas already given; their generic and specific distinctions are as follow:

GENUS I.—LIGHTER THAN WATER.

Species 1.—Oxygen supports combustion vividly; is sparingly absorbed by water; refracts light feebly.

Species 2.—Hydrogen is inflammable, and possesses a peculiar odour; refracts light powerfully.

Species 3.—Nitrogen extinguishes flame; is not itself inflammable; and is devoid of odour.

Species 4.—Chlorine possesses a yellow colour, pungent odour, and spontaneously inflames phosphorus.

CLASS II.

The second class (metals) agrees with the previous definition, and may be characterized by differential properties, as under:

GENUS I.—DECOMPOSE WATER AT COMMON TEMPERATURES.

Species 1.—Potassium inflames when brought in contact with water at common temperatures, even with ice.

Species 2.—Sodium does not inflame with cold water, but scintillates with warm; and if the heat be sufficient, inflames.

Species 3.—Lithium has not been fully examined.

Species 4.—Barium sinks in strong sulphuric acid; and if water be added, forms a sulphate insoluble in any acid or alkaline solution.

Species 5.—Strontium imparts a blood-red tinge to the frame of the blow-pipe.

Species 6.—Calcium forms lime when thrown into water, its hydrate parting with water at a red heat.

Species 7.—Manganese, very infusible; decomposes water slowly at common temperatures, but with rapidity at a red heat.

GENUS II.

The metals in this class, by union with oxygen, form earths; the first of which, magnesia, is an alkali.(*a*) The whole genus burns vividly when heated in the open air, and are for the most part distinguished only by their specific gravities.

Species 1.—Magnesium forms an alkali when burned in the open air or in oxygen gas.

Species 2.—Aluminium: when burned in air, its resulting oxide is characterized by great infusibility; solubility in alkaline solutions, and its want of taste and smell.

Species 3.—Glucinium: its oxide has a sweet taste, thus distinguishing it from other metals of the same class.

Species 4.—Yttrium is of a scaly texture, being thus distinguished from the preceding metals.

(*a*) An alkali is known by its reddening turmeric paper.

Species 5.—Thorium, very little acted on by acids or alkalies, its oxide being insoluble in all acids but sulphuric.

Species 6.—Zirconium appears as a black powder, but has not been carefully examined.(*b*)

GENUS III.—METALS WHICH DECOMPOSE WATER AT A RED HEAT.

Species 1.—Zinc burns with a green flame when exposed to a dull red heat.

Species 2.—Iron is attracted by the magnet, fibrous texture, &c. See page 109, for its characteristic property.

Species 3.—Tin: malleable to a considerable extent, fuses at 442°F. Heated to whiteness, it burns with a white flame.

Species 4.—Cobalt is a brittle metal, specific gravity 7.834; is attracted by the magnet, and is oxidized when heated in open vessels.

Species 5.—Nickel forms a green solution (nitrate of nickel) in nitric acid, and is attracted by the magnet.

Species 6.—Cadmium is very volatile; very much resembles tin in appearance; but, owing to its volatility, it cannot be heated to whiteness, and burn like that metal.

GENUS IV.—METALS WHICH DO NOT DECOMPOSE WATER AT ANY TEMPERATURE.

Species 1.—Arsenic: very volatile, sublimes without previous liquefaction, its vapour having a strong odour of garlic.

(*b*) The properties of the metals in the preceding genus have been so little examined, that it is impossible to give any very decisive specific distinctions; they are obtained with difficulty, and therefore, in an analytical table of differential properties, are of no great importance.

Species 2.—Chromium: yellowish-white colour, very brittle and infusible; not attacked by sulphuric, nitric, or muriatic acids.

Species 3.—Vanadium is not dissolved by boiling sulphuric, hydrochloric, or hydrofluoric acids; but by nitric it is attacked and forms with it a blue solution.

Species 4.—Molybdenum is a brittle white metal, which has never been obtained in a solid state.

Species 5.—Tungsten: heated to redness in the open air, it inflames, being converted into a yellow substance, which is called tungstic acid, but does not act upon litmus.

Species 6.—Columbium inflames when heated to redness, leaving a white residue which has an acid action, reddening litmus paper.

Species 7.—Antimony is a brittle metal of a bluish-gray colour; heated to a full red heat, and then exposed to the air, it inflames; during this combustion a white vapour rises, which condenses as a cold surface, forming crystalline needles of silvery whiteness.

Species 8.—Uranium: very imperfectly known.

Species 9.—Cerium: volatile, but imperfectly known.

Species 10.—Bismuth sublimes without change in close vessels; but, heated in the open air to its subliming point, it burns with a bluish-white flame. When its solution in nitric acid is put into water, a copious precipitate of subnitrate ensues.

Species 11.—Titanium: hardness very great; resists the action of nitric and nitro-hydrochloric acid, but is oxidized by being strongly heated with nitre.

Species 12.—Tellurium: heated before the blow-pipe it inflames, burning with a blue-green flame, and is dissipated in pungent fumes.

Species 13.—COPPER, distinguished from all metals, exeept titanium, by its red eolour, and from titanium by its solubility in nitrie aeid.

Species 14.—LEAD: its solution in nitric aeid is decomposed by hydriodate of potassa, a yellow preeipitate of iodide of lead resulting.

Species 15.—MERCURY, liquid at ordinary temperatures.

Species 16.—SILVER, aeted on by sulphurie and nitrie aeids. When fused in open vessels, it absorbs oxygen in eonsiderable quantity, amounting to twenty-two times its volume, whieh it parts with on cooling.

Species 17.—GOLD, distinguished from all other metals by its yellow eolour; when intensely heated, it is eonverted into a purple oxide.

Species 18.—PLATINUM, speeific gravity 21, being the heaviest of all the metals; insoluble in all aeids exeept nitro-hydroehlorie.

Species 19.—PALLADIUM.

Species 20.—RHODIUM.

Species 21.—OSMIUM.

Species 22.—IRIDIUM.

These four last are all found in the ores of platinum; they are very infusible, and are dissipated in sparks before the oxyhydrogen blow-pipe: for their charaeteristie properties the reader is referred to Dr. Turner, page 651, and *seq*.

CLASS III.

All the substanees in this elass agree with the definition previously given, except iodine, which has a semimetallic lustre.

GENUS I.—SOLIDS.

Species 1.—Carbon infusible. The diamond, which is carbon in its purest form, consumes in oxygen, forming carbonic acid.

Species 2.—Sulphur: peculiar odour; inflames spontaneously in the open air when heated above 300′F.

Species 3.—Selenium: odour of decayed horseradish when heated before the blow-pipe.

Species 4.—Phosphorus: inflammable, entering into slow but luminous combustion at ordinary temperatures.

Species 5.—Boron, dark olive colour; neither taste nor smell; very infusible, but inflames at 600°F.

Species 6.—Silicium: incombustible in air or oxygen; insoluble in nitric, hydrochloric, or hydrofluoric acids; but dissolved by a mixture of nitric and hydrofluoric acids; not changed by ignition with nitre or chlorate of potassa.

Species 7.—Iodine: when moist, it causes the spontaneous inflammation of phosphorus; and when heated, it is dissipated in beautiful violet fumes.

Species 8.—Fluorine: not ascertained.

GENUS II.—LIQUIDS.

Species 1.—Bromine: its fluidity; blackish-red when viewed by reflected, and hyacinth-red when by refracted light.(*c*)

The student in chemistry is next to be made acquainted with the combinations of these fifty-five elementary bodies. The laws governing these combinations have

(*c*) Tables of this character might be drawn up, by means of which the chemist might with precision determine the composition of any substance by referring it to its class, then to its genus, and lastly to its species.

already been explained in the preceding Treatise, and the nomenclature has been detailed in the Introduction. The mode of ascertaining the atomic weight has been already determined: but, for the convenience of the reader, let us suppose that the atomic weight of any elementary substance was required—say carbon; the mode of proceeding would be, first to find a substance which contained carbon as one of its constituents, (carbonic oxide,) and to analyze 100 parts of this substance. Upon resolving carbonic oxide into its constituents, by galvanism or any other agent, we should find the 100 parts (by weight) of carbonic oxide to contain 56.66 of oxygen, and 43.34 of carbon. Now the atomic weight of oxygen is known to be 8; consequently $\frac{56.66}{8} = 7.08$ will give the number of equivalents of oxygen in 100 parts; therefore $\frac{43.34}{7.08} = 6.12$ will give us the weight of one equivalent of carbon, as there must be 7.08 equivalents of carbon in the 100 parts. Or we may at once find the atomic weight (supposing oxygen = 1) by $\frac{43.340}{56.66} = .765$, which $.765 \times 8 = 6.12$; or the weight of the equivalent on the hydrogen scale.

The determination of the specific gravity is the next point of importance. By specific gravity is meant the weight of equal quantities (*i.e.* equal in size) of different elements.

The standard with which gases are compared is atmospheric air, while water is unity in reference to liquids and solids. The exact weight of a given quantity of each of these is of importance, and the method of ascertaining it should be as simple as possible. The specific gravities are all supposed to be taken when the barometer stands at 30 inches, and the thermometer 60°F.

To find by experiment the density of a gas, the greatest care must be taken to render it free from all impurities. It is quite irrelevant here to enumerate all the precautions for ascertaining the exact weight of any gas; I therefore shall merely give the data by which the specific gravity of any compound gas may be calculated.

DATA FOR CALCULATING SPECIFIC GRAVITIES.

1. One volume is the standard to which all gases may be referred as to their specific gravity.

2. The specific gravity of any compound gas may be determined by adding together the specific gravities of the portions of its constituents present in one volume.

3. The weight of 100 cubic inches of air, is 31.0117 grains, (number found by Dr. Prout,) which is the weight of the standard gas; air being = 1.

4. The specific gravity of oxygen is 1.1025.(*d*)

Let it be required then to find the specific gravity, nitrogen.

Atmospheric air is proved by analysis to consist of 0.79 of nitrogen, and 0.21 of oxygen.

Then, by data 1 and 2,

$$\text{sp. gr. of nitrogen} \times 0.79 + \text{that of oxygen} \times 0.21 = x;$$

$$\text{or sp. gr. of nitrogen} \times 0.79 + 1.1026 \times 0.21 = x;$$

$$\text{or sp. gr. of nitrogen} \times 0.79 + 0.231546 = x;$$

$$\therefore \text{sp. gr. of air} = 1 - 0.231546 = \text{sp. gr. of nit.} \times 079;$$

$$(i.e.)\ \frac{.768454}{0.79} = .9727 = x; \text{ or sp. gr. of nitrogen.}$$

Again: let the specific gravity of hydrogen be required.

(*d*) By Dr. Turner's permission, I here insert a correction of a formula, page 190, in the Elements of Chemistry, which perhaps may mislead: the formula is as

$$31.0117 : 34.109 :: 1 : 1.1025;$$

instead of 34.109, read 34.193; which gives 1.1026, or 34.1903, which gives 1.1025.

Water is a eompound of 1 part by weight of hydrogen, and 8 by weight of oxygen; or, by volume, its eomposition is 2 volumes of hydrogen to every one of oxygen.

Therefore, supposing hydrogen (in plaee of air) the standard of speeifie gravities, 1 volume of oxygen would be 16 times heavier than 1 of hydrogen; beeause 1 equivalent of hydrogen contains 2 volumes, whieh multiplied by $8 = 16$.

$$\therefore \frac{1.1026}{16} = \text{sp. gr. of hydrogen};$$

$$\therefore \frac{1.1026}{16} = 0.069 \text{ nearly.}$$

The speeifie gravities of the solids and liquids are found by eomparing equal bulks of these with water.

The ehemieal student has now only to make himself master of the properties of the elementary substanees, and of their eombinations, whieh last, as exemplified in the Treatise, are governed by fixed laws.

There is some doubt as to the propriety of commeneing the study of ehemistry in this manner. A very high authority reeommends the beginner to proeeed by commeneing with the eompound bodies, and so by analysis traee them up to the elements. The authority to which I allude, is His Graee the Arehbishop of Dublin, in the Introduetion to his admirable Treatise on Logic. "The complaint has often been made by ehemieal students, who are wearied with deseriptions of oxygen, hydrogen, and other invisible elements, before they have any knowledge respecting such bodies as eommonly present themselves to the senses; and aecordingly some teaehers of ehemistry obviate in a great degree this objeetion, by adopting the *analytical* instead of the *synthetical* mode of proeedure, when they are first introducing the subject to beginners; *i. e.* instead of synthetically enumerating the elementary substanees, proeeeding next to the simplest eombination

of these, and concluding with those more complex substances which are of most common occurrence, they begin by analysing these last, and resolving them step by step into their simple elements: thus at once presenting the subject in an interesting point of view, and clearly setting forth the object of it."*

I am afraid that I shall be subjected to the charge of presumption in attempting to combat so powerful an author; but really the above passage, how true soever the theory may be, is perfectly useless as a rule for practice. It resolves itself into this: supposing each of the simple substances to combine with ten others as the average number, the student is to be made acquainted, by way of facilitating his progress, with ten times fifty-five substances instead of fifty-five. Again: the passage itself contains a *fallacy;* for "those more complex substances" are not of "most common occurrence," and this seems to be the premis which, being assumed, is to prove the truth of the conclusion. The whole range of metals is surely more common, that is, more *familiar* to the beginner than protoxides, protochlorides, and so on. I again apologize for venturing to attack our ablest logician; but on a point where chemistry is concerned, I must apply the little knowledge I may have acquired.

* Dr. Whately's Logic, p. 19.

Table of the Elementary Bodies, and of the Dates of their discovery.

CLASS. I.—GASEOUS.

Element.	By whom discovered.	Date.
1 Chlorine	Scheele . . .	1774
2 Hydrogen	Cavendish . .	1776
3 Oxygen	Priestley . .	1774
4 Nitrogen	Rutherford . .	1772
CLASS II.—* SOLID, NON-METALLIC BODIES.		
5 Boron	Gay Lussac . .	1808
6 Bromine	Balard of Montpelier	1826
7 Carbon		Known to the [ancients.
8 Fluorine	Not yet obtained .	
9 Iodine	Courtois . . .	1812
10 Phosphorus	Brandt . . .	1669
11 Selenium	Berzelius . .	1818
12 Sulphur		Known to the [ancients.
CLASS III.—METALLIC BODIES.		
13 Aluminium	Wöhler . . .	1828
14 Antimony	Basil Valentine .	1490
15 Arsenic	Brandt . . .	1733
16 Barium	Sir H. Davy . .	1807
17 Bismuth	Agricola . . .	1530
18 Cadmium	Stromeyer . .	1818
19 Calcium	Sir H. Davy . .	1807
20 Cerium	Hisinger and Berzelius	1804

* One exception, bromine is a liquid.

Element.	By whom discovered.	Date.
21 Chromium	Vanquelin . . .	1797
22 Cobalt	Brandt . . .	1733
23 Columbium	Hatchet . . .	1802
24 Copper	Known to the ancients	
25 Glucinium	Wöhler . . .	1828
26 Gold	Known to the ancients	
27 Iridium	Tennant . . .	1803
28 Iron	Known to the ancients	
29 Lead	Ditto . . .	
30 Lithium	Arfwedson . .	1818
31 Magnesium	Bussy . . .	1829
32 Manganese	Scheele . . .	1774
33 Mercury	Known to the ancients	
34 Molybdenum	Hielm . . .	1782
35 Nickel	Cronstedt . .	1751
36 Osmium	Tennant . . .	1803
37 Palladium	Wollaston . .	1803
38 Platinum	Wood, in Jamaica .	1741
39 Potassium	Sir H. Davy . .	1807
40 Rhodium	Wollaston . .	1803
41 Silicium	Berzelius . .	1824
42 Silver	Known to the ancients	
43 Sodium	Sir H. Davy . .	1807
44 Strontium	Ditto . . .	1807
45 Tellurium	Müller . . .	1782
46 Thorium	Berzelius . .	1829
47 Tin	Known to the ancients	
48 Titanium	Gregor . . .	1791
49 Tungsten	D'Elhuyart . .	1781
50 Vanadium	Sefström . .	1830
51 Uranium	Klaproth . .	1789
52 Yttrium	Wöhler . . .	1828
53 Zinc	Paracelsus . .	16th century.
54 Zirconium	Berzelius . .	1824

INDEX.